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A Review of Modern Engineering Practice.

Edited by BEN. H. MORGAN.

VOLUME V.

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Photo by] [Elliott & Fry.

PROF. JOHN PERRY, M.E., D.Sc., F.R.S.

President of the Institution of Electrical Engineers.

The Engineering Times.

Vol. V. JANUARY, 1901. No. 1.

A Prosperous New Year!

With this number we commence a new volume, a new year and a new century. In our four preceding volumes, we have dealt largely with the growth and development of trade and engineering during the past century, and we, therefore, do not propose to attempt here even a short review of the combined advances made under either of those headings. Suffice it to say that in both trade and engineering the new century sees Great Britain still leading the nations of the world, and though the daily press, from the highest organs to the lowest sensational sheets, aver that we are falling behind in the race of progress, we maintain that we are not only not falling behind, but are steadily advancing. British manufactories have never been so full of such well-paid-for work as they are at the present moment, and we believe that when orders become scarcer, and competition keener, British enterprise and determination will still hold for Great Britain the foremost place amongst the nations. It is, therefore, with every confidence in the future that we wish our readers prosperity throughout the new year of the new century.

Personal: Professor John Perry, F.R.S.

As an instructor in the science of engineering Professor Perry occupies a position of great eminence. Few men have had so far-reaching an influence upon rising generations of engineers. His originality and energy must have infused new life and enthusiasm into many who have come under his power in the course of their theoretical training for the calling of engineering. Born in Ireland fifty years ago, he seems from the first to have devoted himself to science and engineering. Before he had reached his majority, he was a B.E. of Ireland, and had obtained Whitworth and various other awards. The aptitude which obtained for him a mathematical scholarship has been always very fully developed, and no man has done more for present day engineers in simplifying the application of the mathematical calculus. His views regarding the inadequacy of the theoretical knowledge and the ability to use mathematics on the part of English electrical engineers have been set forth by him quite recently, in unmistakable terms, in the capacity of president of the Institution of Electrical Engineers. His numerous writings and lectures on mathematical and physical science need not be referred to here in detail. "Practical Mechanics" and "Spinning Tops" are well known. He has always looked more or less ahead, for about twenty years ago he was lecturing before the Society of Arts on the future development of electrical appliances; and in 1900 he has endeavoured to lead electrical engineers

to study the signs of the engineering times, so that they may be fully prepared for what the future has in store. The system of mechanical engineering examinations, adopted by the City and Guilds Institute, is due to Prof. Perry. He can claim not only to have exercised an influence over *English* engineering training, for he has been as far afield as Japan, where, twenty-five years ago, he occupied the post of joint-professor of engineering in the Imperial College of Engineering. For a number of years Prof. Perry laboured in partnership with Prof. W. E. Ayrton, and many valuable inventions of practical electrical apparatus were produced by their joint efforts. One of these, relating to electric surface contact tramways, is of particular interest at the moment, as being a very early and ingenious attempt to solve a very important problem. Like most electrical engineers who have any particular views as to the future of electricity supply, he attaches enormous importance to the provision of electrical energy at large generating stations in the neighbourhood of the colliery for distribution over large areas at economical rates. He recently advocated the adoption of such measures before Parliamentary Committees. Prof. Perry is just now giving great attention to the protection of magnetic observatories from electric tramway return currents. His views are not coincided in by electric tramway engineers, who naturally attach far greater importance to efficient transport facilities than to the maintenance of accurate magnetic records. In his Electrical Engineers' Presidential Address he endeavoured to explain that the course he was pursuing was not opposed to the best interests of electrical engineering.

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Schemes before Parliament.

The latest date for filing applications for Parliamentary powers for the first session of the new Parliament was December 1st, and a study of these schemes shows what an enormous amount of work is at hand for the electrical engineer. If even a mere fourth of the electrical applications for lighting, tramway, and railway undertakings are sanctioned and carried into practical effect, the capital expenditure represents many millions of pounds. The electric lighting projects, for the most part, affect the smaller towns and districts, chiefly in the provinces. This is but natural, seeing that all large towns and cities now have electricity works in operation. There are numerous applications from companies and municipal bodies desirous of installing trolley lines; but in no department is there such a rush for powers as in the underground electric railway section. Such projects, affecting the metropolis only, are legion, and if the promoters have their way, facilities will not be wanting for travelling between almost any two points in London. If carried out, they will make much work for the engineering and electrical industries; but whether they will all pay the investing public is, we are glad to say, a question which is not altogether within our province to discuss. Electrical power distribution schemes for new districts not included in last year's applications are in evidence, and there are several important measures affecting the electrification of the Metropolitan "Underground," and the London County Council's tramways.

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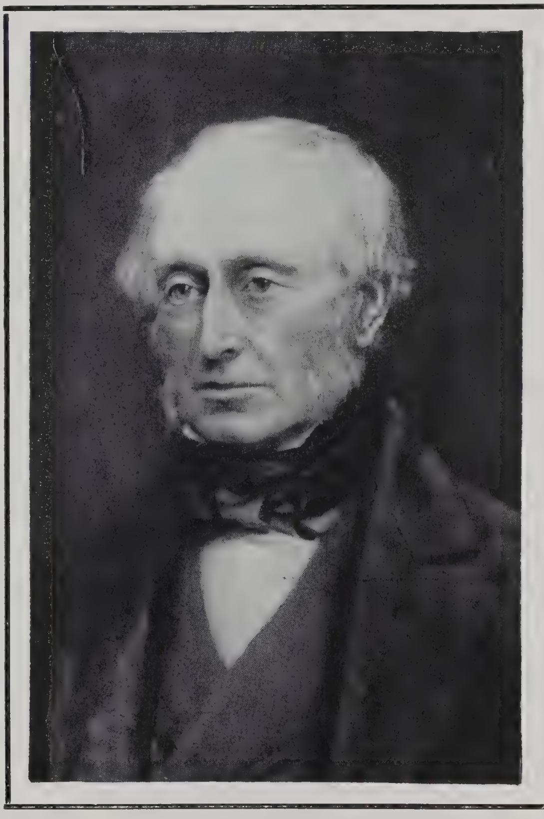
The late Lord Armstrong.

In the person of the late Lord Armstrong there has passed away one of the most notable engineers of the nineteenth century. Death occurred at his Northumberland seat, Cragside, Rothbury, on Thursday last, December 27th. Born at Shieldfield, Newcastle-on-Tyne, on November 26th, 1810, he was consequently ninety years of age.

Many of our readers are doubtless

aware that at the commencement of his career Lord Armstrong was destined for the law, and it was not until he had reached his thirty-seventh year that he quitted that profession for that of engineering. He was, however, always an engineer at heart, and while practising as a lawyer, gave striking evidence of his mechanical inventive genius. His first invention—at least the first we know of—was an automatic hydraulic wheel for converting a column of water to motive purposes. This did not realise what he expected of it. His next invention was his now well-known hydro-electric machine, which procured his admission to the Royal Society. The practicability of his hydraulic machinery was demonstrated in 1845 when he obtained the consent of the Newcastle Corporation to apply the water in the street pipes in the lower parts of that town to the working of the cranes upon the quay. The success of these cranes led to their adoption at the Liverpool Docks, and similar ones have since been introduced to all the great ports of the world. The Society of Arts awarded him the Albert Gold Medal for this important invention. In 1847 he started the works at Elswick for the manufacture of hydraulic machinery, and later he established an ordnance department for the construction of improved types of artillery. He was afterwards appointed Inspector-General of Rifled Ordnance to the War Department, which appointment, however, he relinquished after a few years' service. He then returned to the Elswick Works, which rapidly expanded under his undivided attention, and which were soon working at their full capacity in the manufacture of ordnance, from the small field guns to the monster battleship types. The Elswick firm in 1882 amalgamated with Messrs. Charles Mitchell & Co., and the two concerns were formed into a limited liability company with a capital of two millions—afterwards increased to three millions.

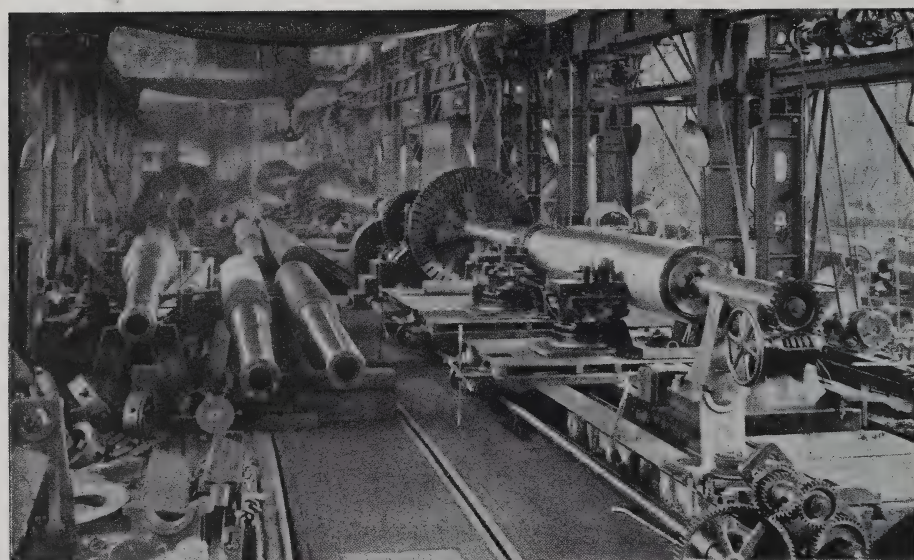
In 1896 the firm amalgamated with that of Sir Joseph Whitworth & Co., under their present style of "Sir W. G. Armstrong, Whitworth & Co. (Limited)." On presenting his patents to the nation Mr. Armstrong was knighted, and in 1887 his great services to his country were recognised by his elevation to the peerage. Lord Armstrong was president of the Institution of Civil Engineers in 1882, and has thrice been president of the Institute of Mechanical Engineers.



THE LATE LORD ARMSTRONG.

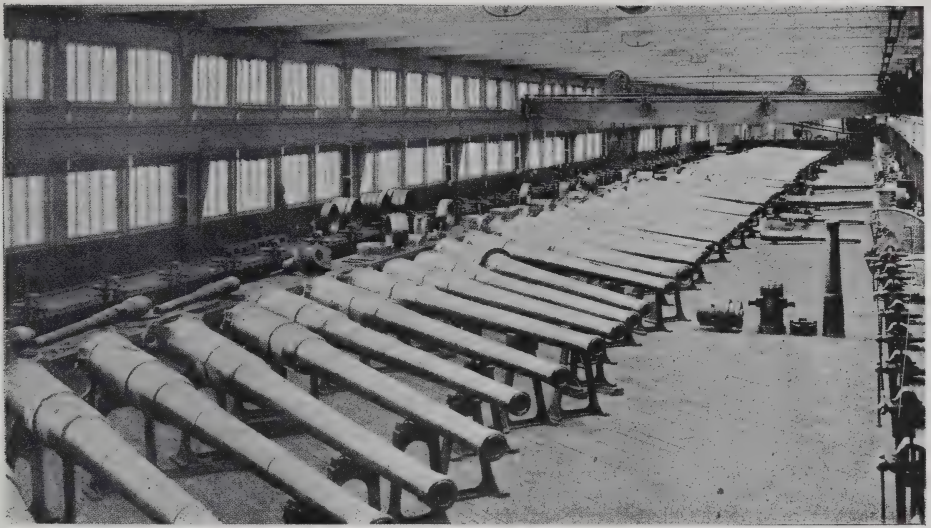
The Armstrong Gun.

It was while reading an account of the battle of Inkerman that Lord Armstrong's attention was directed to the improvement of artillery. The requirement of the day was for light guns with a long range, the short bore cannon of the time being inefficient for any service at all proportionate to their expense, transport and manipulation. Then it was that Lord Armstrong, after many experiments, produced a gun with a steel barrel, rifled on what he denominated the "polygroove" system (*i.e.* with a large number of shallow grooves). The steel barrel was supported externally by hoops or jackets of wrought iron, which were constructed by winding a long bar when red hot round a mandril, and so forming a cylinder having the appearance of a closed helical spring. This was then welded, and the cylinder formed with solid walls, the fibre of the metal running circumferentially, thus presenting the best condition for resisting circumferential strains. Each cylinder was then machined to the required dimensions for passing over either the steel barrel or the first layer of wrought-iron jackets. This process came to be known by the term "built-up" guns. The cylinders were first expanded by heat, and then "shrunk on" the interior tube by the effect of the contraction of the metal that ensues during its cooling. This had the consequence of compressing the barrel whilst expanding the cylinder, giving great strength without additional weight. The enormous importance of the "built-up" system may be gathered by the fact that, prior to its origination by Armstrong, all heavy guns had been cast in one piece.



A VIEW IN A GUN MACHINE SHOP AT THE ELSWICK WORKS.

The success of the new weapon was instantaneous, and at once rendered obsolete the cast-iron weapon. Its accuracy and range, in comparison with all contemporary practice, were simply marvellous. The Armstrong gun of that time would make no contemptible appearance when matched against even the latest developments in artillery of



GUN FINISHING SHOP AT THE ELSWICK WORKS.

the present day. The mechanical difficulties in the construction of the Armstrong were at first prodigious. It must be remembered that the inventor had not merely to invent, but in addition, to instruct his workmen, to devise machinery and methods, with all the other innumerable details inseparable from the founding of a new industry.

The extent of the obstacles in his way may be gauged by the circumstance that he was during two years incessantly occupied with an order for six guns, which it occupied him that space of

THE JAPANESE BATTLESHIP "YASHIMA," BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD.

time to produce. Lord Armstrong also introduced at this time a breech-loading mechanism.

Between the years 1859 and 1863 Lord Armstrong produced over 3,500 guns ranging from 2·5 in. to 7 in. calibre, and to-day, as everyone knows, every nation in the world employs the gun of this great engineer to defend its rights and liberties. To what a mammoth concern the firm of Sir W. G. Armstrong, Whitworth & Co., Limited, has grown may be realised by the fact that at their Elswick and Walker-on-Tyne establishments alone some 24,000 men find permanent employment, exclusive of those employed in coal-mining and the company's works in Italy. It is estimated that upwards of 80,000 people are more or less dependent on the company, whose extensive operations, it must also be mentioned, includes the building of war vessels of all descriptions. We are able to produce some photographs cognate to these works and productions.

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Three-Phase versus Direct Current.

Polyphase systems are employed in connection with a number of English lighting nd railway plants of large capacity, but the comparative advantages of direct current and three-phase distribution for small installations has just been discussed in a recent contribution to the Manchester Electrical Engineers. Mr. H. A. Earle, M.I.C.E., M.I.E.E., raised as his chief point whether distribution from sub-stations should be by polyphase or direct, and whether for smaller installations one system offers such advantages over the other as to warrant a preference being given. The conclusions arrived at were that in many cases where lighting alone is required, the first cost is very similar, but the simplicity of "direct" (both as regards wiring and regulation of voltage) gave it the preference. The same system was considered to possess decided advantages where a number of motors are on circuit, whether the system included lighting or not; and, further, batteries could not be employed with polyphase systems, even for a night load.

* * *

Electric Tramways in South Lancashire.

The South Lancashire Tramways Act, passed last session, authorised the construction of an expensive system of electric tramways for the transport of passengers and goods in the populous districts lying between Manchester and Liverpool. The scheme, which is the largest ever embraced in a private Act, extends to 84 miles of tramway track, and establishes a network of lines commencing at Eccles, near Manchester, and terminating at the borough boundary of St. Helens. The line then passes over 22 miles of track belonging to the Corporation of St. Helens, and taking up the route of the Prescot and Liverpool Light Railway, which is in reality an electric tramway, proceeds direct to Knotty Ash, at the boundary of the city of Liverpool, where it joins the system belonging to the Corporation of that city. The aggregate length of these lines is altogether 107 miles, and the importance of the system will be realised when it is stated that it establishes unbroken tramway communication between the cities of Liverpool and Manchester. All the principal towns of South Lancashire are touched *en route*. The population of the district numbers several millions, so that there is an assurance of an immense passenger traffic between the several districts.

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High Railway Speed in France.

One of the new four-cylinder compound engines now at work on the Chemin de Fer du Nord in France made an interesting run recently. These engines weigh 63 tons each, without

their tenders, which latter weigh 45 tons. The weight behind the tender on the occasion of the trip was 277 tons. The run was from Paris to Charleroi. On the down grades the speed rose to over 76 miles per hour, and one level stretch of 30 miles was run at an average speed of 68 miles per hour. On the next stage of the journey, six miles out from St. Quentin, a gradient of $9\frac{1}{2}$ miles long, and 1 in 200, was taken at an average speed of $58\frac{3}{4}$ miles per hour; and, in fact, the speed never fell below 55·9 miles per hour at any part of the incline. On the return journey the load behind the tender was 300 tons, and the engine was let go on the long incline between Survilliers and Paris, a distance of $4\frac{1}{2}$ miles, at a speed of $80\frac{1}{4}$ miles per hour. Of this distance, 3 kilometres ($1\frac{7}{8}$ miles) were taken at a speed of 81·8 miles per hour.

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Central London Railway.

During the first few days after the opening of the Central London Railway the number of passengers carried was about 100,000 per day. This is equal to about 36,000,000 per annum, or six and a quarter millions per mile per annum. As the traffic develops and the train service becomes more frequent, there is no doubt that more than seven million passengers per mile per annum will be carried. The running time of the trains corresponds to an average speed of 14 miles per hour, including stops, and requires a maximum speed between stations of from 24 to 28 miles per hour. Thirty-two electric locomotives have been provided, as it is intended eventually to have a two-minute service, requiring 28 trains. Each train consists of seven long eight-wheeled bogie carriages, weighing about 150 tons loaded, with a seating capacity for 336 passengers. The interior of the cars is arranged on the central corridor principle, with both longitudinal and cross seats. Entrances are at the end of each car, and are provided with swing gates manipulated by the conductor, after the style of the New York Elevated Railway. The success of the Central London Railway should banish the last vestige of doubt from the minds of the directors of the Metropolitan and District Railways as to the practicability of carrying out at once the scheme which they have now been considering for several years. The new line has been working only three months, but the *Railway and Tramway World*, in a very interesting article on this novel railway, states that the underground steam lines are already feeling the effect which the improved conditions of travel by electric traction have secured.

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"What is a Civil Engineer?"—Omission.

Through a printers' error the acknowledgment was not made in the usual way that the excellent paper, "What is a Civil Engineer?" by Mr. Frederick J. Rowan, was one read before the Glasgow Association of Students of the Institution of Civil Engineers, and as this sheet goes to press later, we hasten to make the *amende honorable* here.

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Testing Laboratories.

Professor Bovey's article describing the equipment and some of the work done at the McGill University, Montreal, which appeared in our last issue, has attracted so much attention that we have arranged for a series of such articles to appear in the *Engineering Times* during the present year. We shall also supplement these articles with descriptions of some testing machines exhibited at the Paris Exhibition.

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Power Gas and Large Gas Engines for Central Stations.

The above is the title of one of the most interesting and valuable papers

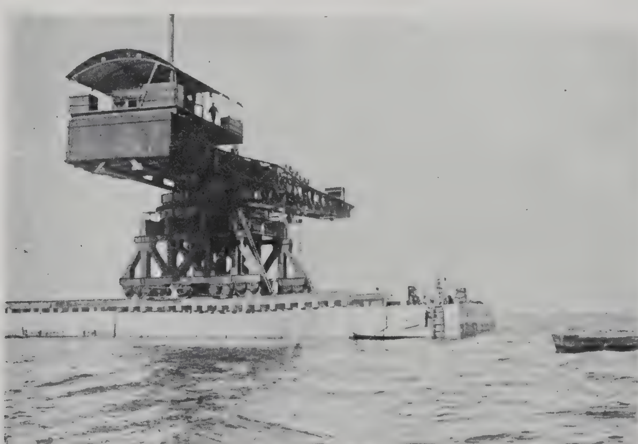
recently presented to the members of the Institution of Mechanical Engineers. The author is Mr. H. A. Humphrey, of Norwich. We have not the space to deal fully with it here, but we give one or two points from it.

The average total cost of a unit of electricity generated by electric-supply undertakings in this country in 1898 was 2·81*d.*, of which the expenses of generation were 1·79*d.* There were certain companies who were prepared to supply electric energy for power purposes at 1*d.* per unit, but even this figure was too much for manufacturers who required large currents, and who could not pay more than $\frac{3}{4}$*d.* per unit. How was this cheap current to be obtained? He believed by the use of power gas and large gas engines. The objections to the use of gas engines for the purpose had disappeared since the introduction of the Mond producer-plant. By using Mond gas the fuel cost per unit of electricity generated was, including all cost of labour, repairs, etc., at the gas-producer and recovery plant, less than $\frac{1}{20}$*d.* per unit at the switchboard, as proved by actual practice at Winnington.

The special features of gas engine practice which have enabled gas engines to be made of powers far beyond those formerly thought possible were then briefly dealt with.

America, France, Germany, Belgium, and lastly Britain, were now turning out large gas engines, and the author had information to show that the orders for large gas engines exceeding 500 h.-p. collectively amounted to over one hundred engines. With such results before them, the time had arrived for a careful study of the advantages to be gained by the adoption of a combined Mond producer-plant and gas engines; and the subject might be considered under the following headings:—(*a*) The possibility of using cheap fuel, and of recovering its ammonia; (*b*) the greater economy of gas engines as compared with steam engines; (*c*) the simplicity and reliability of gas engines; (*d*) the advantages of gas producers over steam boilers; and (*e*) cost.

A most interesting discussion followed the reading of the paper, which discussion will be continued on the 18th instant.



THE BACTERIAL TREATMENT OF SEWAGE.

By E. BROOKE PIKE, F.C.S.

THE sense of hope, in which the interested inquirer may now approach the sewage problem, was unknown to the searcher of a decade ago. If hope existed, it was foredoomed to an early disappointment, for the hundred and one processes and patents extant were, in the majority of cases, more remarkable in their promises than in their achievements.

Most people have a very hazy notion (if they possess any at all) of what sewage is really like. The sewage of London, which includes all rainfall, street washings, &c., is a river whose volume of fully 200 million gallons a day would be represented by a canal 8 ft. deep, 40 ft. wide, and 19 miles in length. When it rains over such a large area as London's drainage system covers, the volume is, of course, very largely augmented. This river of sewage contains suspended solids (that is, solid particles floating in the water) amounting to only about 30 grains per gallon; or, more graphically, 1 lb. of solid matter is distributed through 233 gallons of water. About half of this solid matter is of an organic nature, and liable to putrefaction. But the sewage also contains a large quantity of organic matter in solution which, unless it be either got rid of, or a radical change effected in its constitution, will cause the liquid to undergo subsequent putrefaction, even if the suspended solids have all been previously removed.

With regard to precipitation processes by the aid of various combinations of chemicals, sewage can be freed, in a greater or smaller degree, from the solid matters in suspension; but the impurities held in solution are, in no case, removed to any considerable extent. If, therefore, the process were capable of removing the whole of the suspended solids, and producing a liquid in appearance like clear water, it would, owing to the foul matters held in solution, presently putrefy, and become an abomination.

Land treatment, or so-called "filtration" through soil, was work carried out on what we now know to be the right lines; but it had several drawbacks: the necessity for a very large area of land of a sandy or porous nature (George Thudichun calculates that the sewage of London would require one hundred square miles of the most favourable soil for its treatment if the solids were not previously removed); the difficulty of preventing the land becoming water-logged and refusing to absorb the constant onflow of sewage; in wet weather, when the land was less capable of absorbing extra moisture, a greater bulk had to be disposed of, if, as in most places, the rainfall was included in the town sewage.

With the advent o the Bacterial System, the big difficulties of sewage disposal vanished. The process is simplicity itself, and is of such general interest, that, although many pamphlets and articles have already been published on the subject, a description of the process will well bear repetition.

The sewage itself contains a multitude of minute living organisms, belonging to the vegetable kingdom, called bacteria, which are capable, under favourable conditions, of transforming the complex organic substances contained in sewage into soluble inoffensive gaseous and mineral matters. Given the necessary conveniences, the sewage will work out its own salvation. These conveniences are supplied most satisfactorily in two ways: one, the Dibdin or Sutton System, which depends entirely upon the action of aërobic bacteria (bacteria requiring air for their existence); and the other, the Exeter or Septic Tank System, in which the work is first prepared for the aërobic by the action of anaërobic bacteria (those existing in the absence of air).

In the first-named method the sewage is led into a bed or tank filled with fragments of coke, or other material, of about the size of walnuts. The bed is filled to a level just beneath the surface, and the sewage allowed to remain in contact with the coke for two hours. The liquid is then drawn from the bed by means of an outlet at the bottom, myriads of bacteria being left behind in the interstices of the coke. As the liquid is drawn from the bottom of the bed, air takes its place from above, and the bacteria, in contact with this air, multiply at an amazing rate, and feed upon the refuse which has been left clinging to the coke fragments when the liquid was drawn off. A very faint conception of the huge numbers of bacteria which may thus be harnessed to the purifying plough, may be obtained when it is considered that half a pint of London sewage will often contain as many as two thousand millions of these bacteria, and their reproductive power reads like a fairy tale. A single bacterium will, in half an hour, break in halves, leaving two bacteria in the place of one; in another half hour these two bacteria will have reached maturity—bisected themselves, and there will be four, and so on. In this way half a pint only of sewage would, in the course of five hours, account for a production of 205 million millions of bacteria! Fortunately for humanity, the life of bacteria hangs upon a very delicate thread, and a change in the conditions of, say, temperature, effectually disposes of myriads; still, there are always sufficient left to carry on the task of supplying a coke bed with a complete working population.

At the second filling of the bed the process is repeated, the bacteria which have already taken up their residence meanwhile attacking the sewage for their food supply, and thus effecting the constitutional changes resulting in its purification. It may well be asked, what becomes of the surplus population? The answer is simple. If the bed becomes overstocked with bacteria, the food supply becomes insufficient; the "surplus" dies from inanition, and becomes food for the survivors.

A surfeit of food will encourage the growth of anaërobic, or putrefying, bacteria at the expense of aërobic, or oxidising, bacteria. Therefore, while a bed is "young" and the bacteria not fully developed in number, it is given one filling a day; as time goes on and the bacteria thrive and increase in numbers, two, three, and eventually four fillings a day may be dealt with.

In its passage through a coke bed, as described above, the sewage is purified to the extent of about 50 per cent., calculated on the dissolved impurities alone; but in addition to this, nearly all the suspended solids are also removed. If urther purification be desired, as would be the case were the final liquid to be discharged into a relatively small stream, or one where a high standard of purity was required, a simple repetition of the above process would be necessary, in a bed consisting cf a somewhat finer grade material. This secondary

treatment would remove any trace of suspended solids remaining in the first bed effluent, and would further remove about 50 per cent. of its dissolved impurities.

In the Exeter or Septic Tank System, the place of the first, or coarse coke bed is taken by a closed-in tank, into which the sewage is conducted through pipes below the surface of the liquid, when the tank is three-fourths full. Air is thus excluded, and the growth of anaërobic, or putrefying, bacteria encouraged. The part these bacteria play is that carried on naturally when an organic substance putrefies and becomes converted into gases and water. The solid particles of an organic nature in the sewage become partially dissolved in this tank or chamber, and the resulting liquid is allowed to flow into a coke bed, where the aërobic bacteria complete the work by oxidising the dissolved impurities, and bringing into solution and oxidising the eight or ten grains per gallon of suspended impurities still remaining in the liquid, in the manner described in the first-mentioned system. The Septic Tank is, in fact, simply a glorified cesspool, and presents another instance of the old saying that there is nothing new under the sun; for I suppose this most modern method of disposing of sewage is also the most ancient the world has possessed since civilised communities existed.

The resolution of the foul matters of sewage into inoffensive materials is mainly carried out in the following stages—First, the nitroferous organic bodies are broken down into ammonia, which combines with the carbon dioxide gas, held in solution by the sewage, and forms ammonium carbonate. This is converted by the bacteria into nitrous and nitric acids. These acids, immediately on forming, combine with alkaline bases usually present in sewage, and constitute harmless neutral soluble salts, which are carried away in the liquid flowing from the bed. This may be either run into a stream, or, if desirable, applied to crops, which would, in this way, obtain the manurial value of the sewage in a most assimilable form, and unattended with the objectionable features usually obtaining upon an ordinary sewage farm.

The above is a description of the general features of the two principal bacterial processes. There are, however, many details which are vital to the success of the method, amongst the chief being the necessity for thorough aëration of the beds. The microbes depend for their existence upon the oxygen they derive from the air—therefore, after a bed has rested full for two hours, during which the bacteria are at at work upon the liquid and part of the solid impurities, it should be allowed a "draining period" of, at least, several hours, during which, in the presence of air, the bacteria recoup their energies, and actively attack the putrescible matters in the solid particles, or "sludge," which has been left behind in the interstices of the bed when the effluent has been drawn off. Another detail of very great importance is the provision of a preliminary tank or catch-pit, through which the sewage flows, and becomes freed from the sand and other heavy mineral matters, and from cellulose substances, such as water-logged wood-fibre (derived from wood paving), chaff (from horse sweepings), paper, etc., because, as a graphic gentleman once put it, "Bacteria can hardly be expected to digest granite!" and the cellulose substances are but slowly acted upon by bacteria. If, therefore, these substances were not kept back, a bacteria bed would gradually become choked, and the air space, or liquid capacity, of the bed would diminish until the bed eventually became useless.

The purification of sewage by

bacterial means was mainly the outcome of an exhaustive series of experiments carried out by the Massachusetts State Board of Health, U.S.A., and in the early days London did much to bring the process into a more practicable working form. But, alas! London lags, and still deals with her sewage by the now antiquated method of precipitation with chemicals, while many of her little sisters, availing themselves of the knowledge and experience she has gained and published to the world, are profiting by her labours, and are now well on the way to what we may anticipate will prove a final and satisfactory solution of their difficulties. Nevertheless, in extenuation, it must be borne in mind that London would have risked a very grave censure were she to have committed herself to such a huge undertaking as would have been entailed by the conversion of the precipitation into the biological system, without having first thrashed out every detail of so radical a change. A third report will very shortly be published by the London County Council on the experiments carried out at the outfall stations, the contents of which show that the matter is not falling into abeyance; but thinking people are beginning to murmur that the time and the subject are now ripe for a trial on a more extensive scale than the report indicates, and they would like to see London back up her opinions by advancing from the comparatively small scale experiment into a trial of a really practical nature. If she were to commence, say, by instituting beds and plant capable of dealing with a tenth of her daily sewage flow, and that should prove a success—as all reports certainly lead us to believe—she might then lay down further plant capable of dealing with another tenth. By proceeding in this way the constructive cost would be spread over a long period, and any later improvements or developments might be introduced as the work progressed. In this way, too, the sewage effluent, which increases in volume with the population, would gradually improve in quality, and its effect on the river which finally receives it would be prevented from being obnoxious or even perceptible, and we might reasonably hope at last to see Father Thames cleansed from the slime with which generations of past want of knowledge has clothed him.

E. Brooke Pike

PUMPS: THEIR CONSTRUCTION AND MANAGEMENT.

By PHILIP R. BJÖRLING.

Consulting Engineer and Author.

(*Continued from p.* 551, *Vol. IV.*)

PLUNGER AND PLUNGER PUMPS.

THERE are three types of these pumps, namely: — Those in which the two plungers reciprocate; those in which one plunger and one working-barrel reciprocate; and those that have one large and two small plungers.

A plunger and plunger pump in which the two plungers reciprocate is illustrated in sectional elevation (Fig. 30). A is the large and B the small plungers, between which is secured a delivery-clack piece C, provided with a door for access to the delivery-clack. The large plunger, A, works in the lower working-barrel D, which is provided with a suction-clack piece E, also furnished with a door, for access to the suction-clack. F is the working-barrel for the small plunger B. G is the suction-pipe, and H the delivery-pipe or rising main. The two working-barrels D and F are provided with glands and stuffing-boxes for their respective plungers. This class of pumps is in reality double-acting hollow plunger pumps; they have the same advantages as the single-acting type, and the action is the same as the piston and plunger pump, the large plunger being double the area of the small one; hence the suction is single-acting and the delivery double-acting. Two trunnions are provided on the side of the delivery-clack piece C, to which the pump-rods or wood spears are connected. This class of pumps is very compact, and there being two rods they may be carried straight up the shaft, and the pumps, for the different lifts or stages, may be placed between the two rods, and secured by set-offs, therefore occupying very small space in the shaft or well.

Mr. J. C. R. Okes, of London, has designed and patented a very neat arrangement for securing the valves. This pump is illustrated in sectional elevation (Fig. 31) and part sectional plan (Fig. 32). This pump is specially recommended for sewage and sludge. It consists, as the last example, of two hollow plungers, one being one-half the area of the other, working in stuffing-boxes provided in the working-barrels. The enlarged chamber A contains the delivery-valve, which is accessible through the cover B. The suction-valve C is accessible through the cover D. The suction and delivery-valves are of the ordinary clack type; the seats, formed somewhat like an ordinary saucer, are so arranged that they and their respective valves can be removed by simply slackening some screws: in fact, this is so easily done that one pump, in actual work, had the

engine stopped, valve removed, replaced and the engine re-started in the short space of little more than six minutes.

It will be clearly seen by referring to the illustration (Fig. 31), that the clearance space and air-lodges are not very large, and the water or other liquid has a straight flow. the currents not being reversed during the time they pass through the pump. This is of very great importance for sewag pumps on account of the great amount of gas in the sewage. The only place where air can lodge is at E, above the bore of the hollow plunger. To expel that and to charge the pump, a valve F is fitted on the top of the working-barrel, which should be opened periodically.

FIG. 31.

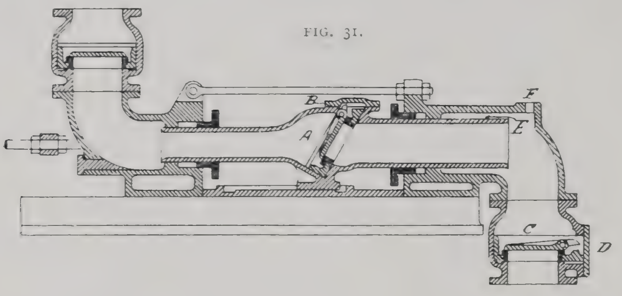


Fig 30

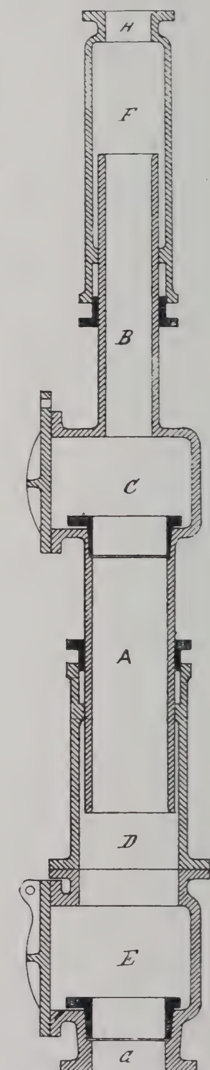


Fig 32

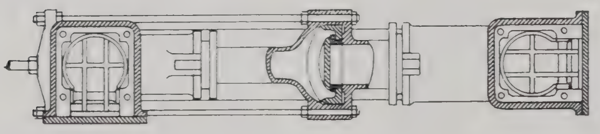
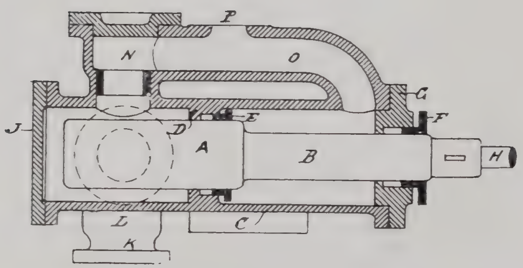


Fig 33



SECTIONAL VIEWS OF PLUNGER AND PLUNGER PUMPS.

The plungers are actuated by means of two rods G, which are coupled at one end to the delivery-valve box, at the other end to a cross-head H, to the centre of which the driving-rod is secured.

This design is of course equally applicable to vertical working, when it will make a very good sinking pump on account of its simplicity and the accessibility of the different parts.

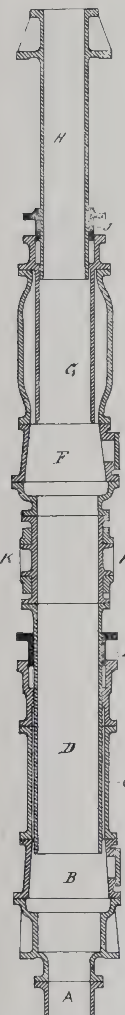


FIG. 34.

A plunger and plunger pump of this class is shown in sectional elevation (Fig. 33), in which both the plungers are closed at the ends, so that no water or liquid can pass through them. It consists of two plungers, A and B, one one-half the area of the other, working in the same pump-body C, which is divided in the middle of its length by a diaphragm D, furnished with a stuffing-box and gland E, in which the large plunger A works; the small plunger B working in the stuffing-box and gland F, provided in the front cover G. The two plungers are coupled to the pump-rod H by means of a cotter. A cover J is provided at the back end of the pump-body for access to the two plungers. K is the suction inlet, L the suction-valve box, secured to a branch on the side of the pump-body; N the delivery-valve box. O is a passage leading to the front end of the large plunger, and P the delivery branch. Frequently the suction-valve box is cast in one with the back cover, instead of being placed on the side of the pump-body, as in the present example. That is a good arrangement, inasmuch that the flow of the water is direct into the working-barrel, instead of passing in to it sideways; but it is open to the objection that, when the cover has to be removed, the suction-pipe joint has to be broken, and two joints to be re-made instead of one.

The second class plunger and plunger pumps, in which one plunger and one working-barrel reciprocate, is represented by a modification of the "Rittinger" pump, which has obtained its name from the inventor, Herr Rittinger, an eminent German hydraulic engineer. These pumps have been adopted by Messrs. Haniel and Luig, of Düsseldorf, in connection with large shaft-boring apparatus on the Kind-Chaudron and Lippmann's systems. It is illustrated in sectional elevation (Fig. 34), elevation of delivery-clack piece (Fig. 35), and sectional plan of delivery-clack piece (Fig. 36). A is the inlet branch or suction pipe; B the suction-clack piece; C is the plunger-case for the large plunger D, this case being fitted with a stuffing-box and gland E; F is the delivery-clack piece, which is bolted to the top of the large plunger

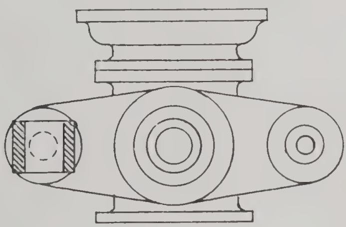


FIG. 35.

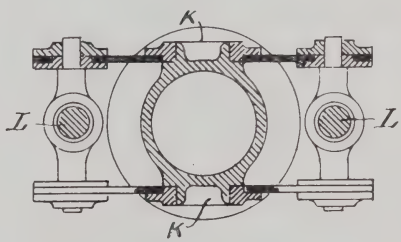


FIG. 36.

D; on the top of the former is bolted the plunger-case G, for the small plunger H, which latter is stationary and forms the rising main; the plunger-case G also acts as a delivery air-vessel. The small plunger-case G is furnished with a stuffing-box and gland J, which slides on the small plunger. K and K are two gudgeons on which work the two pump-rods L and L, the two cross-heads allowing for any vibration of the rods. It will be noticed that the moving parts in this class of pump consist of the large plunger D, delivery-clack piece F, and the plunger-case G for the small plunger. M is a door for access to the suction-valve, and N to the delivery-valve.

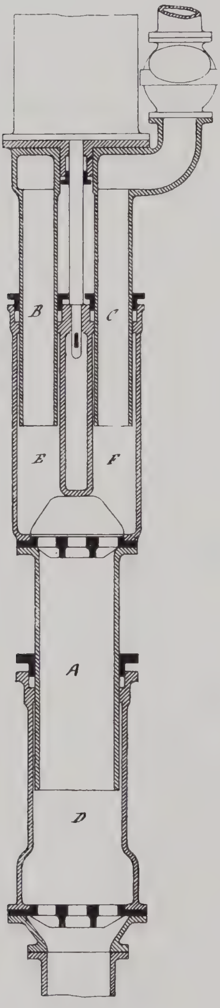


FIG. 37.

The third class of plunger and plunger pump—that is, those which have one large and two small plungers—is represented by the "Denaby" sinking pump, patented by Messrs. Bailey and Lindemann, and manufactured by Messrs. W. H. Bailey, of Salford. It makes an excellent sinking pump, it having the great advantage that every part is well balanced. It is shown in sectional elevation (Fig. 37). In this case we have three plungers, A, B and C; the small plungers B and C are one-fourth of the area of the large plunger A. D is the plunger-case for the large plunger A. E and F are the cases for the two small plungers, and the delivery-valve or valves, as the case may be, is placed in a clack piece formed on the top of the large plunger inside the plunger-case for the small plungers. In the example before us the pump is worked direct from a steam cylinder, and the case for the small plungers is coupled to the steam piston-rod by a cotter. The small plunger B, in this case, acts as an air-vessel, and the water is delivered through the small plunger C, into the back-pressure or retaining valve G.

Advantages and disadvantages of the last three classes of pumps are:—

Bucket and Plunger Pumps.—Advantages:—The pump is double-acting with only two valves, namely, one suction and one delivery.

The pump being double-acting in its delivery, it delivers a more constant stream than the ordinary single-acting bucket pump.

The disadvantages are:—The small area of waterway through the bucket, which produces increased friction.

The friction of the working parts is increased by having both a bucket and a plunger.

Increased friction of water in the suction-pipe, on account of the pump only sucking once in one revolution or double-stroke, which makes the speed of the water in the suction-pipe double that of an ordinary single-acting pump of the same diameter as the plunger. The remedy for this is to make the suction-pipe twice the area of the pipe for a single-acting bucket or plunger pump equal to the diameter of the plunger.

Piston and Plunger Pumps.—The advantage of this pump over the bucket and plunger pump is a large delivery passage, instead of the throttled waterway through the bucket.

The disadvantage is:—The shock produced by the piston meeting and reversing the current of water.

Plunger and Plunger or Ram and Ram Pumps.—The advantages are the same as for plunger and ram pumps of the single and double-acting type, as regards the reduction of wear and tear through sand, grit, mud and other foreign matter; also similar to the piston and plunger pump inasmuch that the pump is double-acting in its delivery, although it has only two valves.

The disadvantages are:—The internal packing for the large plunger.

The shocks produced by the plunger meeting and reversing the current of water; and

The increased speed in the suction-pipe.

WING OR SEMI-ROTARY PUMPS (DOUBLE-ACTING).

This pump, we believe, was originally invented by a German, and was by him termed "Flügel Pumpen," or Wing pump, but since that time it has at various times received different names. Mr. Perkins gave it the name Oscillating or See-saw pump, but at the present time it is generally called the "Semi-Rotary Pump." It exists in two forms—namely, Double-acting and Quadruple-acting.

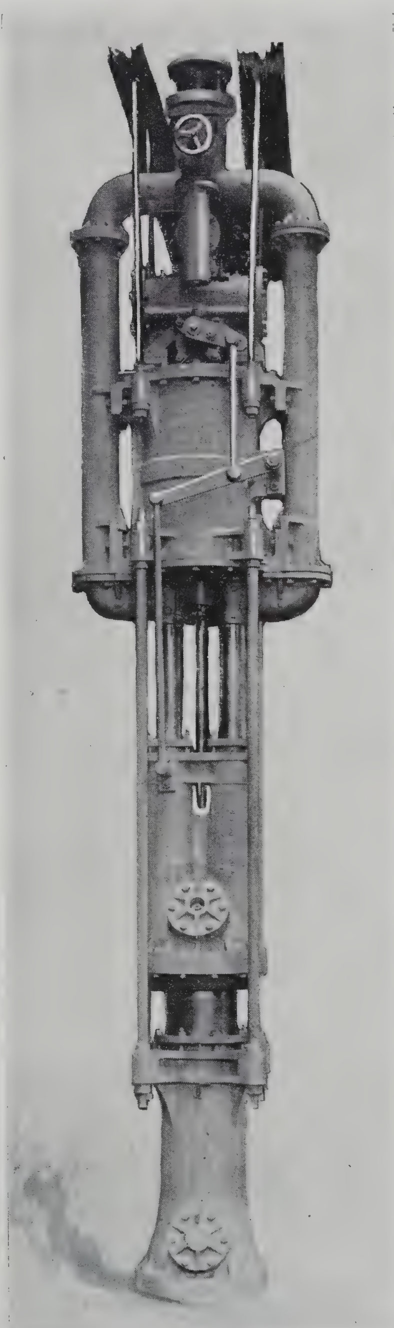


FIG. 38.—THE "DENABY" SINKING PUMP.

An example of the first class is illustrated in half sectional elevation (Fig. 39), and sectional end view (Fig. 40). It was invented and patented by Mr. J. O. Lundberg, of Sweden. The patentee has given these pumps the name, "Flap-valve pumps." The valve-box or cylinder A of the pump is fitted with a cover B, through which passes the shaft or spindle C, on which the flap or wing D is secured. The walls of the cylinder A are hollow all round, and the space E thus obtained is connected below with the suction-pipe F, and serves as a suction air-chamber. The circular space E communicates likewise with the interior of the pump by the ports G, these ports being opened and closed by means of the suction-valves H, on both sides of the pivoted wing D. The top valve J—as usual, placed immediately above the suction-valves—and the arrangement of the wing and the other valves do not materially differ from that of a common semi-rotary pump. The top of the interior of the cylinder communicates with the delivery-branch K. The space E, however, is not partitioned thereby, but, as shown in Fig. 39, behind the enlargement on to which the branch K is secured, the space is narrowed to a passage L, thus effecting the communication between the two halves of the space E. That space can, however, be divided into two parts by filling up the passage L, when suction-chambers are obtained, one for each valve. The cover B is, as usual, secured to the cylinder, packing being laid between the surfaces of contact. In the centre of the lid is a stuffing-box M, through which the shaft C of the wing passes. On the box M, and provided with a screw thread, there is a disc N, having wings O, by which it may be turned round. The under side of the disc N, when screwed down, rests, with the intervention of packing, against a ring P on the front of the cover. Holes are so arranged in the cover that one or more of them, R, extend to the space under the delivery-valves J, and one or more of them, S, to the space above the said valves. When the disc N is screwed away from the cover, the outer ends of the holes R and S will be uncovered, whereby the water in the pump is partly enabled to get out, and the air partly enabled to get in. In

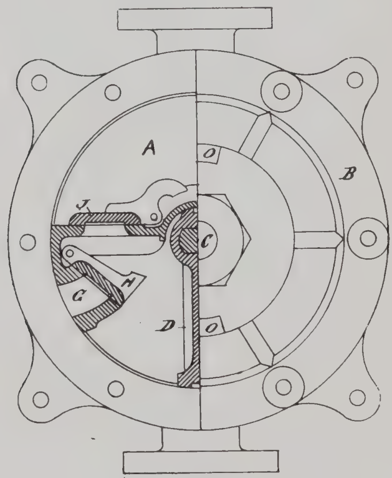


FIG. 39.

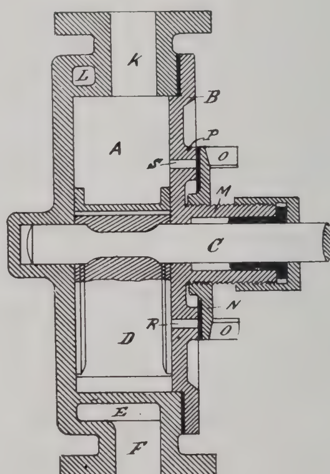


FIG. 40.

order to effect a complete exhaustion of the pump, the wing D should be moved to and fro by means of the lever on the shaft C of the wing, which will facilitate the exit of the water on either side of the wing. The air thus enters through the holes S, and the water flows out through the holes R. By this complete exhaustion, the pump will be frost-proof. The action of the suction-chamber of the pump may be explained in the following manner: — When the pumping commences, there is air in the space E, constructed in the walls of the cylinder. Part of this air goes up through the suction-valves H, by the alternate motion of the wing, and the water is drawn in through the suction-pipe F. When the water has risen up to the ports, it is drawn into the cylinder, while the top of the space E fills more and more with water. Every time the wing is moved towards either side, the water is drawn in through the suction-pipe, in order to fill the remainder of the space or chamber E. When the wing has returned, and one of the suction-valves is opened, the pump acts, on the contrary, by suction on the water in the pipe. Thus it is clear that there will occur no shocks in the suction-pipe, but that a suction exists, and acts even in the turning movement of the wing; and it will be seen that a pump arranged in this manner yields more water than a wing pump of the ordinary construction; and besides this, the suction-pipe may be of a smaller diameter, because the water circulates therein without interruption.

QUADRUPLE ACTION SEMI-ROTARY PUMP.

One of this class of pumps, manufactured by Messrs. W. H. Wilcox, of

FIG. 41.

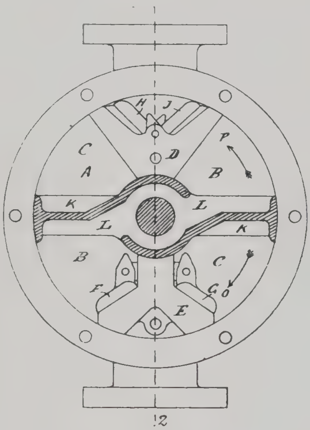
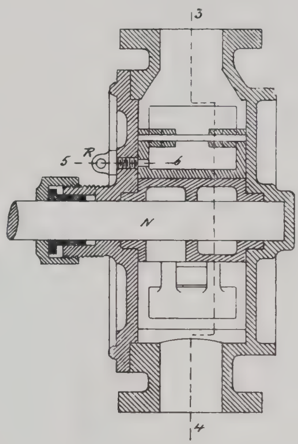


FIG. 42.



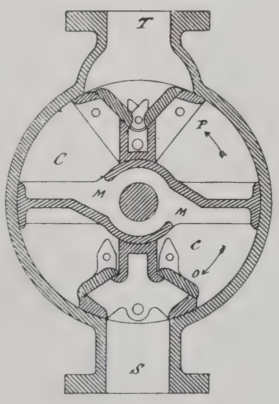


FIG. 43.

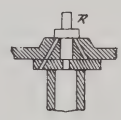


FIG. 44.

WILCOX'S QUADRUPLE ACTION SEMI-ROTARY PUMP.

London, is illustrated, with the front cover removed, in elevation (Fig. 41); cross-section on the line 1-2 (Fig. 42); sectional elevation on the line 3-4 (Fig. 43); and section on the line 5-6 (Fig. 44). A is the cylinder or pump body, which is divided into four compartments, B and B, C and C, by means of two rigidly inserted valve seats D and E, which are

fitted with four valves, F, G, H, and J, and which also serve to support the wings K and K. The wings are not fitted with any valves, but are provided with two central ports or passages crossing each other obliquely. L and L are the passages connecting the spaces B and B, and the passages M and M, similarly establishing independent communication between the spaces C and C.

The action of this pump is as follows:—If the lever, secured to the spindle N, is moved to the right, the wings travel in the direction of the arrow O, and the water or other liquid enters through the suction-valve E, the space B, and thence through the channels L and L into the second space B. If the wings K are then moved in the opposite direction, as indicated by the arrow P, the two spaces C and C are similarly filled through the suction-valve G and channels M and M, respectively, while at the same time the contents of the compartments B and B are discharged through the passages L and L, and delivery-valves J, and so on. R is a screw plug, by removing which the pump can be emptied when the pumping operation is stopped. S is the suction branch, and T the delivery branch.

A Quadruple pump patented by Mr. Lundberg is illustrated in sectional elevation (Fig. 44); and cross-section (Fig. 45). To the end of the cylinder A is secured a collecting or delivery chamber B, from which the delivery branch C ascends. The pump is fitted with eight valves, four for suction and four for delivery. The valves H, J, K and L, in the end M of the cylinder, are provided with strengthening flanges, and are placed on the inner side of the cylinder end, so that they may open inwards to the pump, and thus become the suction-valves. The valves N, O, P and R, are opposite the suction-valves and

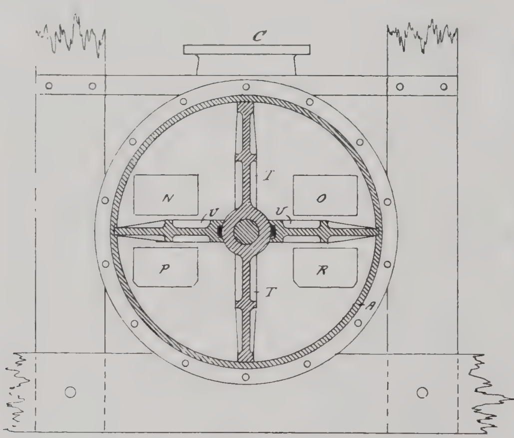


FIG. 45.

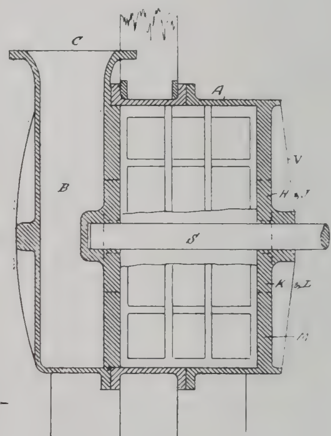


FIG. 46.

open towards the delivery chamber B, and thus they constitute the delivery-valves. On the shaft S, which passes through the pump cylinder, the wings T are fixed; the interior of the cylinder is divided into two parts by the fixed partition wall U, which fits into a groove in the ends and the sides of the cylinder, and extends close up to the centre boss of the wings. By imparting an oscillating motion to the wing, the pump has a quadruple action. A metallic wire gauze, V, is fastened on a projecting flange on the cylinder, and on the centre of the cylinder surrounds the shaft, preventing any solid matter from getting into the pump. These pumps, worked by wind

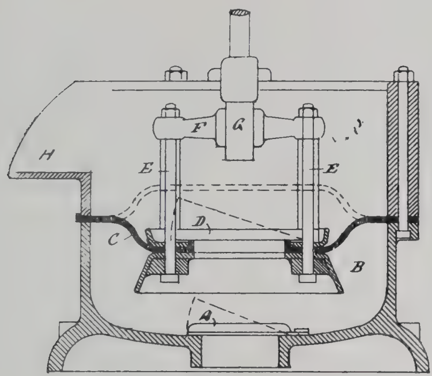


FIG. 47.

in the diaphragm are placed circular flanged plates for stiffening it, and the top plate serves the purpose of the delivery-valve seat, the beat for which is formed by the inward flange of the diaphragm. When the disc is deflected downwards, as shown in Fig. 46, the capacity of the chamber is diminished, and, as the suction-valve prevents the liquid returning into the suction-pipe, it is forced to pass through the delivery-valve in the disc. On the return stroke, that is, when the diaphragm is moved to the position shown by the dotted lines, the pump chamber is enlarged, the delivery-

engines, have for years been successfully adopted for re-claiming land in the Baltic.

The advantages of Wing or Semi-Rotary pumps are: They are simple in construction; not liable to get out of order; and take up very small space.

DIAPHRAGM PUMPS.

The pumps of this class are very useful when foul liquids or acids are dealt with, which will injure the bored part of the pump, and the reciprocating piston.

We represent this class by the "Dando" pump, manufactured by Messrs. Duke and Ockenden, of Littlehampton, which is shown in sectional elevation (Fig. 47), and a reproduction of one arranged on a wrought-iron stand (Fig. 48). A is the suction-valve; B the pump chamber: C the diaphragm, made of india-rubber, in the centre of which is arranged the delivery-valve D. The diaphragm is deflected by means of two bolts, E and E, secured to the cross-head F, and pump lever G. H is the delivery spout, the diaphragm being held firm between that and the pump chamber B. Round the delivery hole

FIG. 48.—THE "DANDO" DIAPHRAGM PUMP.

valve closed, and the suction-valve opened, the water enters the chamber, and so on.

(*To be continued.*)

Philip R. Björling

THE ECONOMIC ASPECT OF STEAM GENERATION.

By W. FRANCIS GOODRICH, A.I.Mech.E.

AS I write this Welsh Steam Coal costs about Thirty Shillings per ton in London. Even the most wealthy and prosperous of steam users have not faced the extraordinary advance in the price of fuel with equanimity, while hundreds of smaller users of steam power all over the country have been, and are yet troubled by an increasing cost of production and consequently vanishing profits.

It is therefore an opportune time to look into the economic aspect of steam generation, although some pessimists would have us believe that steam was produced as cheaply twenty years ago as it is to day.

It will be easy to show that such an idea is utterly fallacious, and that steam is produced at far less cost at this time than was the case even five years ago.

I will go further, and say that steam is produced to-day far cheaper than ever before, and our best steam practice will compare favourably with anything in the world. Simultaneously with that advance in steam pressure with boilers from just above atmospheric pressure to an every-day working pressure of 200 pounds to the square inch and upwards, there has been a remarkable advance in methods of burning fuel to secure the highest efficiency therefrom.

Some few months since, when the Right Hon. A. J. Balfour, M.P., alluded to the rapid exhaustion of the coal-fields of Great Britain, he just incidentally mentioned that in the destructive distillation of coal for the production of steam an enormous waste was involved. To some extent that is correct, but we are improving. It is now possible to usefully employ for the raising of steam over 70 per cent. of the heat units in a pound of coal, and I think we are in a fair way for reaching even 80 per cent., but there are obvious reasons why the irreducible minimum will be found somewhere near an efficiency of 80 per cent.

Coal in many industries is a most important factor in determining the price of the finished product. For instance, in the paper mill it is said it takes so much coal to make one ton of paper. In the dye works we are told each piece of material dyed costs so much in fuel. The flour miller aims at producing each sack of flour at the minimum expenditure for fuel. The brewer, even, is anxious to brew so many barrels of beer at the lowest possible cost for fuel, and so on. It would be a simple matter to multiply these examples, but the four representative trades mentioned will suffice to show that fuel cost is a vital factor in fixing the cost of production.

Therefore it is most astounding that so many steam users in this country have in the past attached so little importance to the question of securing the maximum efficiency from the fuel they have to purchase in enormous quantities at high prices.

There are a number of large firms in this country who have gone most exhaustively into this question, and they have been amply compensated. A number

of large and eminent British firms might be named who day by day watch most carefully to see that each pound of coal consumed yields up the maximum of its heat units.

Nothing is taken for granted ; a regular system of fuel analysis is instituted, and an equally regular and careful analysis of the residue. The gases of combustion are sampled periodically, and tested. Temperatures are taken—in short, most exhaustive trials are constantly being made and logged for reference.

What is the consequence ? Practice approximates to theory. Any shortcoming is at once detected, traced to its source, and remedied. Responsibility is fixed, from the moment the coal is delivered until it gives up its residue.

It will be at once said, "Yes, this is all very well, but it is altogether too scientific, too elaborate, most unnecessary, and expensive." This is often said by the British steam user imbued with a dogged conservatism, but what is the case on the Continent and in America ? There the man in the same industry takes an altogether different view. He does not scorn the scientific, he is full of enterprise. If any innovation will tend to cheapen production, then he is interested.

The writer was reminded of this some time since, when looking into the sales of an instrument for recording any excess of air passing through the fires. On looking into the matter, I found that for every single instrument sold here, upwards of forty were sold in Germany, Switzerland, and generally all over the Continent.

We hear much nowadays about foreign competition, lost markets, and so forth, and yet hundreds of manufacturers in this country will not seriously face the question of cheaper production.

It may be said that fuel is only *one* item: that there is the vexed labour question present always ; and a rising market for the raw material, maybe ; also other factors all operating against cheaper production. This may be so, but surely the mere fact of fuel being only *one* item is no logical reason why it should not be considered ?

Delve into the economics of steam production, produce the power at the minimum of cost, save all that is to be saved there, then the other factors in production can be tackled so much better.

Waste in these days is a terrible mistake. If our largest manufacturers find it advisable to face the matter, is it policy for smaller manufacturers to despise the methods of their bigger rivals, and to sneer at the foreigner, who, to a large extent, is enabled to produce his wares cheaper because of his enterprise ?

To drive this home, let us take a concrete example. On the Continent a large number of tanneries derive the whole of their steam power from their spent tan. I have in mind one very large tannery at Strasburg, where not an ounce of fuel is used but spent tan ; but be it noted the tan is burned under proper conditions, in a specially constructed furnace.

Compare this with many cases in this country, what do we find ? For the most part tan is not seriously considered as a fuel, and, extraordinary to relate, in many instances coal is actually used to burn the tan. The steam user would say, "Nonsense, I am burning coal and tan." Exactly, but the tan would not even smoulder without coal to burn it under ordinary conditions. There you have it exemplified. Such a man would waste half a ton of coal per day to burn a similar quantity of tan, and would not consider a means of saving the coal and burning the tan properly. Why should he do so ? "He can burn it without your patent, as he has done for twenty years past." What is being done at Strasburg and in many parts of the Continent might be done here in the

larger tanneries, if a capable firm was consulted.

Those who have travelled through the manufacturing centres of Great Britain know that only severe competition will wake many out of their astonishing lethargy. If only the fittest are to survive, much remains to be done yet in the economical generation of steam.

Unfortunately, many of the inventors of devices for economical steam generation and smoke prevention are men who have had little, if any, practical experience of that great question which they consider they have solved.

How simple and catchy their solution appears on paper, or as a tin model, and how its proud possessor chuckles, and goes forth to seek his victim, the hapless steam user. The more innocent the victim, the more easy the inventor's task.

For an unadulterated enthusiast, give me the gentleman with the tin model furnace : it is impossible to find his equal. If he would only seek out the practical steam user, the world might know more about him before his invention ends in smoke, where it also began. But such inventors have a holy horror of the practical man, who makes an exhaustive test, and has the chimney watched for a few days by the clock, and every minute of smoke tabulated.

This is not the victim, but, instead, the smaller steam user, who is not practical, and so for a time is deceived. While this period lasts, this alleged success is used as a decoy for others unwary. A little later, emboldened by fancied success, the inventor tackles the man who does know, and this is the beginning of the end. A few such men, and the bubble is burst—the end comes ; an end which has come to scores during the past twenty years.

When will the steam user cease to encourage such misdirected energy, which touches his own pocket ? When will he learn to follow the lead of our largest steam users—people who know too much to be gulled ?

The small steam user might wisely do as the largest firms are doing. They have spent thousands to arrive at correct conclusions. Miles of paper or models would not impress them. They have learned to see through paper, and can at once recognise the practical. Many such firms are always ready to give a trial to a real practical improvement. If you have no facilities for learning the practice of large steam users, then be warned. Do not purchase any device unless it is offered by a firm of experience and reputation, and will bear the closest investigation.

HAND FIRING FIRE-BARS.

In order to get a reasonable grasp of this subject, it will be advisable to consider each so-called panacea separately ; so first of all we will take patent fire-bars. It will be obvious that within the limits of such an article as this, it will be impossible to deal with every fire-bar introduced. We can but take a few representative types.

It is really extraordinary to find that such a very simple part of a steam raising plant could have been so conjured with, and offered to the steam user in such bewildering variety. The productions of the last ten years even in patent fire-bars are almost innumerable. Some have been fairly extensively adopted ; many have had a very short existence ; while large numbers have never got beyond the paper stage. And for this the steam user has reason to be profoundly thankful.

Perhaps the fire-bar, apart from the ordinary plain bar, which has found the most favour has been that of the hollow type. At one time it was claimed that a bar of this type would prevent smoke, largely increase the steam-raising capacity of the boiler, or enable small cheap fuel to be employed.

It will be said, "This is a large order."

Yes, but it was all claimed persistently; theoretically, it was not possible. Practice confirmed this, but the luckless steam user was led to believe what he was told, only to be quickly disillusioned, and to come to the conclusion that patents could not help him to economise.

Here I would say that I make no reflection on makers of fire-bars generally. The mischief is caused by men who are sent out to sell—men who are not engineers, and who will promise anything to get business. These are the men who have done much to stifle enterprise in the steam user, and caused him later to look with considerable suspicion upon inventions of value.

The hollow fire-bar, in course of time, assumed various forms. One development was the introduction of a hollow bar, with a crude steam jet blowing into the front end of each bar. This was to some extent successful, under favourable conditions, in burning such fuels as pea anthracite; but a transverse steam pipe with some twenty or twenty-five crude steam jets, each with an orifice of two or even three millimetres, could only be expected to use an enormous amount of steam, and a quantity utterly out of proportion to any advantages which might be derived from the apparatus.

This arrangement was never very extensively adopted. It could not be. It would not effect any improvement in a really difficult case.

Another development was a hollow bar with a very large bore. With this the buyer was definitely assured of perfect combustion, which, under favourable circumstances, he may have got. But the inherent mischief with all patent bars has been that most extraordinary promises have been given, altogether regardless of conditions.

For instance, what patent bar can consume small fuel unless there be a good chimney, a sufficient natural draught; or what would suffice equally as well, or even better, a good forced or artificial draught? To burn successfully small or inferior fuels is a matter of draught, and no fire-bar, however fearfully or wonderfully constructed, is of any good whatever unless an adequate draught exists, or be provided.

Again, if we take the question of smoke prevention or increased steam production, the position is precisely the same. The fire-bar cannot in itself reduce smoke, neither can it materially assist evaporation, except the conditions be favourable.

Briefly, a patent fire-bar is dependent upon certain favourable conditions. If these exist so, well and good. If they do not, as is more often the case, then the specious promises of the salesman are never realised.

Some may say this is gross exaggeration, but I could name a number of large manufacturers who have spent in some instances even as much as thousands of pounds in trying patents to economise and prevent smoke, and they are still periodically fined, and they much prefer that process rather than further experiments. This explains much of the scepticism and apathy prevalent to-day.

FIRE DOORS.

Another source of such failure and disappointment has been patent fire doors. One of the first was a perforated door with the baffle at such an angle as to deflect the air passing through directly on to the fire. If the fire was thin, and the chimney draught intelligently regulated, this was useful. If, on the other hand, heavy firing was resorted to, and the chimney draught was very sharp and ample, then there was a constant danger of having a clean chimney, at a great sacrifice in efficiency and economy. Thus, again, it will be seen that a certain combination of favourable circumstances was necessary to ensure success.

Another type of door was the Shutter, or Louvre door. Originally the Louvre arrangement was controlled by a lever, and adjusted at the will of the fireman. Latterly it was automatic in action, the shutters being open after a charge of fuel was thrown in, and gradually closing over a period which could be regulated according to the quantity of fuel fired. This was ingenious, and so far a step in the right direction; but in both cases that vital factor, draught, was ignored entirely, although this alone could make or mar the success of the door.

Stupid as it may seem, scores of steam users were foolish enough to imagine that a door could itself prevent smoke, regardless of conditions. When they are invited to attend the Court they get a rude awakening.

BRIDGES.

Here, again, is a stumbling block over which many a steam user has come to grief. We have had split bridges, hanging bridges, perforated bridges, incandescent bridges, and many more, all more or less alike. Generally speaking, the patent bridge has only been put forward as a smoke preventer, but that same *if* already alluded to is the controlling factor again. The bridge is so far successful *if* circumstances favour it only.

In some instances a steam pipe has been carried through to a split bridge fixed in a boiler flue, working under such conditions as make success impossible. What is the result? Quite as much smoke, but less steam. Other cases could be cited where a crude form of steam jet blower has been fixed in the bridge, delivering a volume of air against the crown of the flue vertically, to some extent minimising smoke, but at the same time spoiling the draught.

It will be seen that each so-called panacea so far mentioned has a common weakness. They are all entirely dependent upon circumstances which may or may not exist.

ROCKING FIRE-BARS.

This was a development from which much was hoped, and accordingly promised, but they have never been very extensively adopted. The usual method of rocking the grate was by means of one or more hand levers.

The main advantage of the bar was to break up the fuel and cause the finer particles to riddle through into the ash-pit. So far this was very effective, but having to provide a good air space, unfortunately unconsumed fuel also passed through.

Further, with a poor draught, and the periodical movement neglected, trouble soon ensued. The bars fused and jammed, becoming immovable and useless.

The rocking bar, like others already mentioned, was only proportionately useful as circumstances were favourable, and therefore caused much disappointment and trouble; and its failure in places where it should never have been sold seriously militated against its adoption in suitable cases.

ARTIFICIAL DRAUGHT.

When artificial draught was first introduced, considerable prejudice was encountered, owing, in a large degree, to ignorance, and also in a measure to the bitter experience of many steam users with the previously described appliances.

Success constantly demonstrated, however, has gradually broken down scepticism and prejudice, and I am well within the mark when I say that since the day of Watt no boiler appliance has found nearly so much favour as forced draught.

Of course there have been failures, but invariably it has been owing to either a crude or badly designed apparatus, purchased because it was cheap, or, on the other hand, extravagant

promises have been made quite impossible of fulfilment.

An ancient Eastern maxim runs something like this: "To get at the real root of failure, you must be critical." As far as in my power lies, I want to make clear to the steam user where he has gone wrong, what he must avoid. That involves some critical remarks, for which I make no apology.

One of the most serious stumbling blocks has been cheapness. The steam user has a certain result in view, and he is credulous enough to think that a cheap arrangement is quite as effective as an expensive one, if there is any similarity on paper.

There are obvious reasons why an apparatus which has to be placed near intense heat should be constructed to withstand the heat. It should be complete. If you decide to adopt forced draught, it is advisable to have a complete job, or none at all.

By a complete job I mean new furnace fronts specially designed for the work, ashpit fronts to fit perfectly airtight, suitable fire-bars, blowers of approved make, designed to do specific work. Such a job is cheap for what there is in it, although it may cost twice as much as a bit, or part of a furnace. There are a number of part furnaces on the market at present. Some consist of a sheet iron ashpit plate and two pipes fixed horizontally under the grate. These are called blowers, but are really nothing of the kind.

There is more in a blower than many imagine. A blower is not merely a pipe shaped more or less like a trumpet; a blower must assume a definite shape, and it must be made to do definite work —that is, it should deliver a given volume of air with a given consumption of steam. The greatest quantity of air delivered for the least steam consumption fixes the efficiency of the blower.

Pipes called blowers are used, the capacity of which for air delivery is an unknown quantity; likewise the steam jet consumption is similarly problematical. This, however, is known, that the quantity of steam used is altogether prohibitive, and is often four or five times as much as that of a properly designed blower.

Thus what the unwary steam user may seek to save in the initial cost is paid forhour by hour in steam—*i.e.*, coal. That is not all. No steam jet blower should be used unless the steam is superheated. This very necessary provision, the superheating of steam, is of immense importance; but it is not a feature of the part furnace.

Again, with the part furnace there is no provision for the prevention of smoke. It is manifestly absurd to say that the blower will prevent smoke; very often it will tend to make the smoke trouble far worse than under ordinary conditions.

The part furnace is often applied to existing fire-bars — another palpable error. It is useless to expect good work from a forced draught when fire-bars with an air space suitable for the chimney draught are retained.

Work of this kind should be given to the experienced engineers of reputation, specialists in furnace work. Until this is recognised there will be failure and annoyance.

One curious development of the forced draught furnace has been a furnace without fire-bars, if I may so call it, the fuel being fed directly into the furnace tube, two or three perforated sectional pipes being placed immediately upon the bottom of the furnace tube. A steam jet blows into each pipe, inducing a current of air.

Heavy fires are carried up to a thickness of, say eighteen inches. It is claimed that the absence of fire-bars is a great advantage, but this is exceedingly doubtful. Great trouble is experienced in cleaning the fires, which is a laborious

and lengthy job, occupying fully fifteen to twenty minutes.

The absence of air space gives no plenum under the fire, and fresh fuel is constantly fed into a vitrefying, clinkering mass. Again, there is no provision for smoke prevention at all.

Given the very best forced draught furnace ever invented, nothing but an intelligent handling of the same will ensure the best possible results in efficient steam raising. Let us for one moment look at the average fireman, and watch his methods. He throws on a heavy charge of fuel, opens the valve, and puts on full pressure, which is maintained until a fresh charge is required, and then the same process is again repeated.

The stupidity of this method will be apparent to the merest tyro. A heavy charge of fuel requires sufficient air, but as the carbon is burned—as the combustion is completed—the fire is reduced in bulk, body, and resistance, and far less air is necessary. The intelligent man would reduce his air supply gradually and concurrently with the condition of the fire.

But the fact remains that, as a general rule, this is not done. Fires are heavily charged and allowed to burn down very low before being again charged, and so at the time when air should be supplied in decreasing quantity, it is supplied in increasing and excessive quantity.

Artificial draught, which, in its simplest form, is represented by the steam jet blower, has made rapid strides in this country, and it behoves the steam user to look carefully into the question ere he decides to spend. It is not my business to give a gratuitous advertisement to any maker, but it is my duty to warn the steam user against appliances which are wrong in principle, and which will only cause vexation and annoyance.

If your dynamo or high-speed engine should break down, you would not call in the blacksmith; that is preposterous. Then why would you hand over your steam boiler to people who are no better qualified to improve it than the blacksmith is to improve your engine?

This is not overdrawn in any sense, but actually represents what has been done by many. Parts of furnaces have been fitted which have simply failed to produce as much steam as could be obtained from the same boiler by chimney draught.

Then the user condemns forced draught, and would not think of applying it again. He forgets that what he has tried is not forced draught, but what might be more truthfully termed false draught.

The addition of forced draught to a boiler is too serious a matter to be given to the inexperienced. Even as you know, it is policy to insure your boiler; so make no error, it is equally politic to countenance no forced draught furnace, but a complete and substantial job in every respect. And, further, employ no furnace of the kind unless superheated steam is used for the blowers.

The fire-bars, also, must be suitable, and part of the furnace. Do not believe that an apparatus worked without any fire-bars at all, will serve you. There are serious disadvantages in working fires without a proper grate surface.

Having now dealt with many of the arrangements, practical and otherwise, which have been adopted more or less by steam users with a view to economy and smoke prevention with hand firing, we will now look into the question of machine firing.

(*To be continued.*)

W. Francis Goodrich

THE CONDITION OF WATER AND POWER DEVELOPMENT IN SOUTHERN CALIFORNIA.*

By L. K. SHERMAN, M.W.S.E.

SOUTHERN California has experienced an unprecedented period of drought. The mean annual rainfall, in the valleys of the Santa Ana and San Gabriel, is about 18 in. During the past three years the annual rainfall has been only 5 in. to 8 in.

In the writer's recent visit, this country was seen in its least favoured condition. Irrigation is the great necessity. With water, this perfect climate and fertile soil bears a luxuriant growth of almost all the products of the temperate and tropical zones. Without water, in the eyes of a tenderfoot, the country is a desert.

The construction of irrigation systems and water-power plant has been carried to an extent so as to utilize almost all of the dry weather run-off. The storage systems have not been so completely developed, but there are several large reservoirs—the Hemet, Sweetwater and Bear Valley reservoirs, with masonry dams; the Cuyamanca, of earth, and the San Fernando submerged dam. There are several projects, proposed and under way, for dam construction, especially in the line of submerged dams for intercepting sub-surface streams.

The development of land is synonymous with the storage and distribution of water. A large part of the land under cultivation was made available by the numerous land and irrigation companies. The amount of water necessary for irrigation varies greatly according to the kind of crop, soil and amount of rainfall. All measurements of water are in California miner's inches (50 miner's inches equal one second foot). One inch of water, on an average, will irrigate eight or ten acres. The duty of water in Southern California is larger than elsewhere, as the scarcity of water has compelled careful and economical methods in irrigation.

The value of irrigated land runs from $40 to $150 per acre. Water is sometimes included with sale of land, and again is sold separately. In the latter case, the annual charge is about $15.00 per miner's inch, or say $1.50 to $2.00 per acre irrigated.

The companies operating water-power plants for electric transmission are generally separate concerns from the irrigation companies. The power companies are compelled to utilize the natural flow of the stream, so as not to interfere with irrigation rights. Water rights are jealously guarded, and are a cause of frequent litigation.

The practice in power development and irrigation head works can be illustrated by a description of some of the typical plants in operation. The power house of the San Gabriel Electric Co. is located near Azusa, at the foot of the San Gabriel mountains. From it come the weirs for distributing the water, after it has left the wheels, to the flumes and ditches, of various irrigators. The electrical equipment consists of four 300 K.W. Westinghouse generators. The current from the machine, at

* Read before the Western Society of Engineers.

500 volts, passes through transformers, and is conducted, at a line voltage of 15,000, to Los Angeles, distant 23 miles. Here the sub-station receives the current the demand for current exceeds the available water power. Oil is used for fuel under the boilers. This is general practice, and will be considered later on.

FIG. I.—VIEW OF PLACER MINING FLUME.

in step-down transformers and four rotary converters, and delivers the current for local power and lighting. In connection with the sub-station is an auxiliary steam plant, which is used as Mr. A. C. Balch, engineer of the San Gabriel Co., is prominent in the development of electric power transmission in the west.

The hydraulic equipment consists of

four sets of Tutthill wheels, two wheels being placed on the same shaft with each generator. The wheels are of the impulse type, and receive the jet of water on buckets, placed alternately right and left on the rim of the wheel, and inclined a little outward. The jet of water is not split during the interval it acts on a bucket. The wheels are controlled by Tutthill and Lombard governors. The governor moves a blade which cuts the jet at the discharge nozzle and reduces the flow.

The general method of conducting water to the wheel in nearly all the power plants is as follows: The line consists of two parts. First, the flume which leads the water from its source in the mountain stream, spring or reservoir in the upper part of the canon. This part of the line is on an easy grade, from 5 ft. to 25 ft. per mile. It follows closely the contour lines on the side of the mountain and delivers the water in a small forebay, 300 ft. to 1,000 ft. above the power house at the mouth of the canon. Second, the penstock, a riveted steel pipe which conducts the water from the forebay to the wheels, down the hill at an angle of perhaps 45 degrees.

The economical location of a line for water power development offers problems that are not excelled in the most difficult railroad work.

The types of construction used for the hydraulic line are:

1. Open wood box flume.
2. Wood or steel pipe.
3. Tunnel.

In practice, combinations are used in the same line, as best suits conditions.

The accompanying views of flumes and pipe lines are not all taken in Southern California, but are given as they illustrate typical construction throughout the west. Fig. 1 is a view of a placer mining flume now in construction at Twin Lakes, Colo. Fig. 2 is a wood stave pipe carrying water for irrigation near Redlands, California.

The cost of the hydraulic line will be given for a few actual cases. However, these figures by themselves do not mean much, as numerous local conditions must be taken into account:

Cost of tunnel in San Bernardino Mts., 5 by 7 ft.	$8.00 per foot.
Cost of tunnel in San Gabriel Mts., 5 by 6 ft.	3.50 per cub. yd.
Cost of 48 in. wood pipe near Redlands, Cal.	2.08 per foot.
Cost of 6 ft. diameter wood pipe	6.00 per foot.

FIG. 2.—WOOD STAVE PIPE CARRYING WATER.

The flume at Twin Lakes, Colo. (Fig. 1), cost 20 cents per foot for carpenter work, including posts cut on ground. The total cost of the hydraulic line at Ogden, Utah, was about $700,000. There are $6\frac{1}{2}$ miles of wood pipe, 6 ft. in diameter, and about 1 mile of 6 ft. diameter steel pipe.

The San Gabriel Electric Co.'s hydraulic line conducts the water in wood stave pipe and cement-lined tunnels. The average grade is 5 ft. per mile. Water is delivered to the wheels, previously described, under a head of 390 ft. through a 36 in. riveted steel penstock.

In Southern California one enters the canons from a plane, from which the mountains rise quite abruptly. There is no evidence of water but the past action in the river bed. The floor of the canon is a hot, dry waste of sand and boulders, with no sign of vegetation, except coarse brush and cactus. But as one travels four or five miles further up, he will come across a thick growth of willows and sycamores, from which a small stream of water trickles, but it is soon lost as it sinks into the gravel. The somewhat paradoxical condition of a stream increasing in size as it nears its source appears.

FIG. 3.—VIEW SHOWING ENTRANCE TO TUNNEL AT THE HEAD GATES.

Submerged dams are built across the canon to intercept this sub-surface flow, to store it and raise the water to a higher level. A submerged dam is now being built by Mr. A. P. Newman, chief engineer for the San Gabriel Co. The trench is 6 ft. wide, excavated through gravel by sheet piling. The depth to bed rock is from thirty to sixty feet. After completion of excavation the dam is to be made by filling the trench with concrete. The pit is pumped by electric current from the power station.

The Southern California Power Co. holds the world's record for long distance electric transmission and high voltage. The power house is located in the canon of the Santa Ana river, near Redlands, Cal. There are four 750 K.W. General Electric Co. generators, each operated by a direct connected Pelton water wheel under 735 ft. head. Originally, an air chamber was attached to the penstock for an equalizer, but this has been abandoned. The pulsations set up by the compressed air added to, instead of remedying, the trouble. A deflecting nozzle is used, operated by a Lombard governor. This moves the nozzle, throwing the jet of water more or less on to the wheel as required. Power is transmitted to Los Angeles, a distance of 83 miles, at the high voltage of 33,000. The engineer, Mr. Pearson, informs us that they have had little trouble with the line, and that it is perfectly successful even in rainy weather. Both the San Gabriel and Southern California plants represent the latest and best engineering in electrical transmission. They are in a successful condition financially. The hydraulic line is about three miles long. It is almost entirely tunnel work. There is one section of wood flume, but it is proposed to replace this with tunnel to avoid falling rocks and land slides, a trouble that is of common occurrence on all the mountain side flumes. Fig. 3 shows the entrance to tunnel at the head gates.

At the time of the writer's visit August, 1900, the electric plant at Sonora had just shut down, and both the San Gabriel and Southern California water plants were running at one-fourth

capacity, due to lack of water. The auxiliary steam plants were run to make up the deficiency.

A proposed dam for a storage reservoir, at the junction of the Santa Ana and Bear Creek forms the outlet of the Bear Valley reservoir, which is fifteen miles above. The reservoir is reached by a drive over the San Bernardino mountains. The scenery on the road is grand. The trail, however, is as steep as a team can hold on to, and in passing it is sometimes necessary to unhitch, or to even take a waggon apart and carry it. The dam which makes the Bear Valley reservoir is well known, as its stability depends almost entirely on its action as a masonry arch. The boldness of its design is somewhat startling. It is four feet thick on top, and has a very little batter on the up stream side. The reservoir was entirely empty. This does not mean that it is a failure or has not served a useful purpose.

Recently, on account of the lack of water in many of the mountain streams and reservoirs, irrigation from artesian wells has been resorted to. Artesian wells have proved very successful. They are sunk from 200 ft. to 400 ft. Sometimes there is a surface flow, but generally pumping over a small lift is needed to raise the water to the irrigating ditches.

Gas engines with centrifugal pumps are used. They are very common. The "bark" of the gas engine can be heard now on almost any ranch in Southern California. There are many types and arrangements of gas engines. One outfit, placed on a sprinkling cart of a suburban road, consisted of a small gas engine and rotary pump. The outfit did not weigh over 200 lb., and filled the cart from irrigation wells.

The fuel used in gas engines is distillate, a product from the California oil wells that corresponds somewhat to gasoline. Distillate costs 8 cents or 9 cents per gallon. Coal is almost unknown. Crude oil is used under the steam boilers. Its cost for power is equal to coal at about $5.50 per ton.

Water pumped from wells is not quite as cheap as water furnished by the irrigation companies, when the latter can be secured. But pumping may be considered as a dry period auxiliary to irrigation, just as the steam engine is to water power. The great success of artesian wells has proved a salvation. I have not disguised the fact that water is expensive and difficult to secure. I wish to say, however, that although there has been no rain since last April, there are few places where the orchards show any of the effects of drought, and the cities of Southern California present an appearance of permanent and substantial growth.

NOTES ON ENGLISH AND FRENCH COMPOUND LOCOMOTIVES.*

By CHARLES ROUS-MARTEN.

(*Continued from p.* 542, *Vol. IV.*)

THIS was not the case, and accordingly the engine, after a somewhat lengthened trial, was decisively condemned, and was converted into the four-cylinder compound "Jubilee."

An additional novelty in the design of this class consisted in placing under the leading end what would be known on other lines as a four-wheel bogie, but which on the London and North-Western is entitled a double radial truck, the absence of a pivot being apparently deemed sufficient to deprive it of any right to the designation of bogie. As the term bogie has always been understood to apply to the truck upon which the leading or trailing end, or both, of an engine or vehicle is carried, without reference to the means by which it accommodates itself to a curve, whether by pivot or sliding action, or otherwise, the difference is one not quite easy to understand. However, the point is not necessarily germane to the specific subject of the present paper, and need not be pursued further on this occasion.

As to the capabilities of Mr. Webb's four-cylinder compounds, the author, in view of his own experience, finds it impossible to entertain any doubt whatever. His first trip behind one of them definitely settled that point. "Black Prince," the pioneer of the type, took up the Scottish day express from Rugby to Willesden, 77 miles, in 83 minutes 39 seconds from start to stop, and in doing so did not run at a higher speed than 65 miles an hour down falling gradients, or at a lower rate than 50 miles an hour up the long banks of 1 in 330. The load, exclusive of engine and tender, was 244 tons, or equivalent to twenty-four south of England coaches. Such a performance alone would suffice to place the hall mark of success on the new engines, and the run was made in the ordinary course without the slightest knowledge or suspicion on the driver's part that his work was being carefully noted. As a matter of fact, the engine evidently ran quite at its ease throughout, and could have arrived several minutes earlier had the train not been already in advance of booked time.

A second experience consisted in the well-known trip of the Members of the Institution of Civil Engineers to Crewe, when the "Iron Duke," the third built of the class, took a load of 339 tons behind the tender, from Euston to Crewe, 158 miles, in 3 hours 10 minutes, in spite of signals and relaying delays amounting in all to 6 minutes, while the speed was maintained at 41, 45, and occasionally 48 miles an hour up gradients of 1 in 330 to 1 in 550, and never exceeded 72 miles an hour down the 11-mile descent approaching Crewe.

* Read before the Society of Engineers, November 5th, 1900.

But perhaps the most noteworthy feature of this run was the ease and certainty with which the four-cylinder compound attacked and climbed the rise of 1 in 70, which is encountered shortly after leaving Euston. Many of the passengers stretched their heads out of the windows and looked backward with keen curiosity to see whether any assistance was given in the rear of the train, but nothing of the sort occurred. The engine simply went straight up the bank of 1 in 70, hauling 339 tons, without the slightest hesitation or difficulty. It is impossible honestly to ignore the conclusiveness of such an illustration of the locomotive's capacity.

The return journey with the identical load was in some respects still more remarkable. The engine had to face at starting the Madeley bank 11 miles long, 3 miles being at 1 in 177 and 4 at 1 in 250, the rest 1 in 330. Up this bank with 339 tons behind the tender, the "Iron Duke" steadily maintained an average rate of 37·5 miles an hour, while up the later rise of 1 in 350 for 6 miles approaching Tring, the speed did not fall below 47 miles an hour; and on the falling grades it was never permitted to exceed 65 miles an hour, or even better time could have been made. As it was, the long distance of 152½ miles without stop from Crewe to Willesden was covered with that immense load in 2 hours 53 minutes, or at the average speed of 52·8 miles an hour. All the observations were made by the author personally.

It has always appeared to the author that such performances as these must be deemed affirmatively conclusive as to the capacity of the engine, and that no subsequent failure, if such should occasionally occur, as it does with every type of locomotive, can be taken into account as against the testimony of such splendid work performed under the observation of a crowd of capable judges and independent witnesses. Is is not his intention to convey the idea that he regards the type as ideally perfect, for that is by no means his view. While cordially recognising all that is admirable in the design, he does not shrink from stating that there are several points which do not commend themselves to his judgment. Among these are the comparative smallness of the boiler, and the plan of connecting all the four cylinders with a single driving axle, which, therefore, has to undergo all the drawbacks incidental to a doubly-cranked axle—viz., its inherent weakness as a column or girder—and to straight axles driven from each end, which, according to the late Mr. Stroudley, suffer from the torsional effect of alternately twisting and untwisting a fibrous structure. But while theoretical exception may be taken to these features in Mr. Webb's design, the practical result as tested by performance is, in the author's experience, unquestionable success.

Much space has been devoted to the consideration of Mr. Webb's various types of compound express engines, because they are virtually the only representatives in England of the compound system as applied to locomotives. That is to say, they are extant as standard classes employed in regular express duty, and their latest type is rapidly being multiplied by the most important railway of Great Britain. The fact is in itself sufficient justification.

It will be convenient now to turn to the other system of compounding which has been in this country the chief rival of Mr. Webb's method, and which at one time threatened to compete closely with it for the favour of the railway world.

In the year 1884, Mr. T. W. Worsdell, then chief Mechanical Engineer of the Great Eastern Railway, constructed a two-cylinder compound express engine

on the system in which his name is now associated with that of Herr von Borries. In taking this new departure, Mr. Worsdell pursued a course diametrically opposite to that of Mr. Webb. That is to say, he did not seek to initiate any striking novelty, but endeavoured to utilise and develop an idea which had been mooted on the same railway so long ago as the year 1847. In conversation with the author, Mr. Worsdell expressly disclaimed any wish to be accredited with the novelty, and declared he was simply expanding an old idea. He also pointed out to the author that his pioneer engine of the new type was absolutely identical with his standard express class on the Great Eastern, except that one of the 18 in. high-pressure cylinders was replaced by a 26 in. low-pressure cylinder, both being kept inside the frames, while the steam from the former was transmitted to the latter instead of being exhausted into the outer air—in short, the compound principle was adopted.

One consequential difference from the standard type involved by the use of a 26 in. inside cylinder, was that a four-wheeled leading bogie had to be substituted for the single pair of radiating wheels which carried the leading end of the non-compound locomotive. Placed side by side, both cylinders drove the same crank axle. The valve-chests were placed in the smokebox, above the cylinders. Steam could be admitted direct into the low-pressure at starting by means of an intercepting valve, so that both cylinders temporarily possessed starting power, while after a stroke or two of the piston the valves were forced automatically by the exhaust steam into their normal position, and compound-working proceeded thenceforward. The results given in practice by the first engine were deemed so satisfactory that ten more were built. The author made several trips on and behind these engines in the years 1884 and 1885, and his experiences were distinctly favourable. The pioneer engine, No. 230, hauled heavy loads at a good speed up such grades as the Brentwood bank of 1 in 84 and 1 in 93, and ran with ease and swiftness on the level and downhill portions of the line.

But it appeared to the author in this case, as it did in that of Mr. Webb's earliest compounds, that the engines were seriously hampered by the limitation of their steam pressure to 160 lb., a pressure at which he cannot believe that compounding can be profitably practised in express work. Also, notwithstanding the fact that many engines of the Worsdell-von-Borries type are at work on the Continent, he cannot approve the lopsided arrangement involved in having a small high-pressure cylinder on one side of the engine and a huge low-pressure cylinder on the other. He is convinced that practically this involves some degree of unequal balance and working, nor is this opinion shaken by any theoretical demonstration, however apparently clear, that the two sides are perfectly equilibrated. This may be the case sometimes, as when an engine is freshly out of the shops, but after a while, or at occasional times, an inequality of pull and power is likely to manifest itself between the two sides, and the boxing action ensues if only to a slight extent. An absolute balance, and, so far as possible, identity between the two sides of a high-speed locomotive are, in his opinion, essential factors of perfect stability.

The Great Eastern compounds did not enjoy a long career, for their author migrated to the North-Eastern Railway the year after he brought out the first of their number, and his successor on the Great Eastern, Mr. James Holden, after a series of careful experiments, decided on the conversion of all the eleven compounds into non-compounds.

As thus converted they are still running and doing good service.

On establishing himself at Gateshead, Mr. Worsdell at once proceeded to build a number of engines on his compounding system for the North-Eastern Railway. Many of these were for goods traffic—but this should be treated as a separate branch of the subject. The compound express engines closely resembled those he had designed for the Great Eastern, but had larger boilers and smaller coupled wheels, viz., 6 ft. 8 in. diameter instead of 7 ft., while in some cases the leading bogie was dispensed with and a radial axle substituted. These engines, although no longer employed on the most important express duty, have done much good service, and still do so on occasion. They are sluggish starters, but have large haulage capacity, and can often develop great speed.

Mr. Worsdell then proceeded to construct ten single-driver engines with identical cylinder dimensions, but with 7 ft. wheels. These, too, performed very efficiently. The author has known one of them maintain a speed of 30 miles an hour up the gradient of 1 in 100 approaching the Bramhope tunnel, with a load of sixteen coaches, or approximately 190 tons, and attain 79 miles an hour with the same load down a falling grade. But both of these types were soon overtaken and mastered by the rapidly augmenting train loads, and a more powerful class had to be produced.

Still adhering to the compounding principle and the single-wheeler type, Mr. Worsdell next brought out ten remarkably fine engines with two inside cylinders of the colossal dimensions of 20 by 24 and 28 by 24 respectively; driving wheels 7 ft. 6 in. in diameter, and boiler pressed to 200 lb. per square inch, 175 lb., however, being used in ordinary practice. Those engines proved remarkably efficient, hauling very heavy loads and attaining very high speeds, a rate of 85·7 miles an hour having been noted by the author, while he has seen time kept on the Anglo-Scottish express between York and Newcastle with loads exceeding 270 tons behind the tender.

It is probable that they would have continued to form the standard express type on the North-Eastern but for one unfortunate drawback. The immense bulk of the low-pressure cylinders left no space inside the frames for the valve chests. These, consequently, had to be placed outside, and so were exposed to extreme variations of temperature, with the consequence that they had a tendency to crack in frosty weather. This defect rendered it necessary to rebuild the engines, and as no convenient method suggested itself of overcoming the difficulty, all were converted into non-compounds by the designer's brother and successor, Mr. Wilson Worsdell, with 19 by 24 cylinders and valve chests inside the frame. Some of the coupled class were also converted, one being a very large coupled engine with 7 ft. wheels, which was built by Mr. Wilson Worsdell to be identical with a new standard express class, save in having his brother's system of compounding. In this case, however, the conversion was not into a non-compound type, but into a new design of three cylinder compound which will be referred to more fully later.

It will thus be noticed that the Worsdell-von-Borries system has passed out of date on the North-Eastern as on the Great Eastern, its exponent engines being simply relics of a virtually extinct method, never intended to be revived in regular practice. It may, therefore, be fairly said that the system has been definitely abandoned on both those railways.

At this stage, instead of pausing to consider the various plans of compounding which have been experimentally and sporadically tried in Great Britain

during the past fifteen years, it will be more convenient to turn to the system which, although designed by an Englishman, has found practically universal adoption in France, as well as extensive acceptance in Switzerland and Germany.

So long ago as the year 1885, Monsieur A. de Glehn, Directeur-General of the Société Alsacienne des Constructions Mécaniques, who is an Englishman by birth, designed a four-cylinder system of compounding for locomotives. It was first applied to an express engine, No. 701, belonging to the Chemin de Fer du Nord, or Northern Railway of France. That had four 6 ft. 10 in. driving wheels, which were not coupled but were worked independently by two 13 in. high-pressure cylinders placed inside, and two 18 in. low-pressure cylinders placed outside the frames, the high-pressure cylinders driving the trailing wheels, and the low-pressure cylinders the middle pair of wheels. This experiment proved so successful in five years' trial that no fewer than six successive series of express engines compounded on Monsieur de Glehn's principle, were designed by Monsieur du Bousquet, the Chief Mechanical Engineer to that railway, between the years 1890 and 1898, the difference between each series and its successor consisting mainly in the continuous development of power. It is needless to describe in detail each advance in the design and construction of the admirable engines which have now become the standard type on every main line in France, a fact no less significant than remarkable, especially seeing that it is wholly ignored in Great Britain, the country of its inventor.

The locomotives constructed on the de Glehn system of compounding, although differing among themselves in details of design according to the various idiosyncrasies of the respective engineers-in-chief, may be roughly classified in two main divisions. In one the engines have four coupled driving wheels 6 ft. 6 in. to 7 ft. in diameter; in the other there are six coupled wheels 5 ft. 6 in. to 5 ft. 9 in. in diameter. In each case the engine has a leading four-wheeled bogie, two high-pressure cylinders placed outside and driving the second pair of coupled wheels, two low-pressure cylinders placed inside which drive the front coupled wheels; very large boilers with Serve tubes and large firebox of the Belpaire type

It will be convenient to take the latest type in each class on the Chemin de Fer du Nord as illustrations of the general principle of the design and of the methods adopted. Prior to the construction in the current year of the new ten-wheeled type of express compounds for the Paris Exhibition—one to be on show at Vincennes and the other to work on the line—all the standard eight-wheeled type on the Northern Railway, fifty in number, had $13\frac{1}{2}$ in. high-pressure cylinders, 21 in. low-pressure cylinders, $25\frac{1}{4}$ in. piston stroke, and 7 ft. driving wheels with new tyres. In these respects all are alike. The gradual changes have been in the development of boiler power. Thus the total heating surface which was 1,671 sq. ft. in Nos. 2.121 to 2.157, was enlarged to 1,892 sq. ft. in the subsequent batches, and the steam pressure which was 199 lb. per square inch in Nos. 2.121 to 2.137, was increased to 213 lb. in Nos. 2.138 to 2.180, and the grate area was simultaneously expanded from 21 to 28 sq. ft., while the weight in working order grew from 47 to 52 tons. The de Glehn compounds constructed for the other French main lines differ only in minor dimensions. Those on the Chemin de Fer de l'Etat are practically identical. Those on the Orleans line, twenty-five in number, have slightly smaller driving wheels, 6 ft. 10 in., and slightly larger cylinders, viz., $13\frac{3}{4}$ in. high-pressure and $21\frac{1}{2}$ in. low-pressure; they also have the

Tenbrinck heater in the firebox. Those of the Midi have the same sized wheels as the Nord engines, but larger cylinders, like those of the Orleans line.

The Est compounds have smaller wheels than any of the foregoing, viz., 6 ft. 8 in., but have cylinders the same size as those of the Orleans and Midi engines, also larger boilers with 1,988 sq. ft. of heating surface and higher steam pressure, viz., 228 lb., which, however, has been reduced since delivery to the usual standard of 213 lb. The Ouest compounds are somewhat smaller and have 6 ft. 7 in. wheels; 1,440 sq. ft. of heating surface and 199 lb. steam pressure, but the same sized cylinders as the Nord engines. The Paris-Lyon-Mediterranée line adopted the de Glehn compound system in 1891, and has steadily increased the dimensions as in the case of the Nord line, the cylinders, however, remaining always the same, viz., $13\frac{1}{2}$ in. high-pressure and $24\frac{1}{2}$ in. low-pressure, with $24\frac{1}{2}$ in. piston stroke, while the coupled wheels have always been 6 ft. $6\frac{3}{4}$ in. in diameter. But the heating surface has been enlarged from 1,594 sq. ft. in the earlier engines of the years 1891-93 (43 in number) to no less than 2,040 sq. ft. in the latest type, which came out two years ago and number as many as ninety.

One peculiarity possessed by these Paris-Lyon-Mediterranée locomotives is, in the author's opinion, the reverse of advantageous. They all have the wind-cutter fronts which some engineers so strangely believe to decrease the atmospheric resistance encountered. Thus not merely is the smokebox front extended in a beak-shape, but the chimney front also is provided with an angular wind-cutter and so are the steam-dome, sandbox, and cab. That the resistance of a wind dead ahead, or of the still atmosphere in calm weather is to some trifling extent mitigated by this mode of construction, may at once be frankly admitted. But in reality it is so small in amount as to be practically negligible. Experiments have shown that the difference in the atmospheric resistance encountered by a flat-fronted cylindrical body and one with a pointed, or angular, or beaked, or prow-shaped front, is relatively so small as to be hardly worth providing against if such provision involve extra cost, or any other drawback.

Were no such drawback incurred even the trifling resistance which the air offers to the progress of a moving body of such small sectional area as a train, might possibly be worth averting. But unfortunately a very serious drawback to the wind-cutter construction does exist, although it seems generally to have escaped notice. While a head wind or a still atmosphere hinders the fastest train but little, any wind in the slightest degree on one side of the course, still more if right abeam, as it is nautically phrased, and most of all if on either bow—that is to say, partly ahead and partly on one side—constitutes a hindrance of a most serious nature, because by forcing the flange of every wheel on one side of the whole train against the lee rail it acts as a very powerful brake. The author has found in direct experiments that such a wind, if strong, will often reduce the speed of a fast express by 30 or even 40 per cent. Now the fatal disadvantage of the wind-cutter construction is, in the view of the author, that it exposes the greatest possible amount of surface to the most mischievous wind of all, and so increases the resistance in a very formidable degree, instead of diminishing it. It is not a little surprising that in the face of this indisputable fact the fallacious idea should still prevail that the wind-cutter front is the ideal construction type for express engines and trains. It is at least noteworthy that the best booked timings on

the lines using this form of construction—which has lately been adopted also on the State Railway—are lower than on any other French line, but this is not mentioned as a case of cause and effect, being rather *post hoc* than *propter hoc*. The coincidence may nevertheless be recorded.

The engines of the six-coupled type, which are being more and more used in France, as elsewhere, on heavy express service, have 5 ft. 9 in. coupled wheels, on the Nord, Est and Orleans lines; 5 ft. 9 in. and 5 ft. 3 in. on the Midi; 5 ft. 5 in. and 4 ft. 11 in. on the Paris-Lyon-Mediterranée; 5 ft. 7 in. on the Ouest. The high-pressure cylinders on the Nord, Orleans, Midi, Est and Ouest railways are $13\frac{3}{4}$ in. in diameter; on the P.L.M. $13\frac{1}{2}$ in. and $14\frac{1}{4}$ in. respectively. The low-pressure cylinders are mostly $23\frac{1}{4}$ in., and the piston stroke, which is $25\frac{1}{4}$ in all other cases, is $25\frac{1}{2}$ in. on the P.L.M. The heating surface is respectively as follows:—Nord, 1,945 sq. ft.; Ouest, 2,088; Orleans, 2,023; Midi, 1,956; P.L.M., 1,665 and 2,039; Est, 2,210. The steam pressure is 213 lb. in the case of the Nord, Orleans, Midi, and P.L.M.; 228 lb. originally—now 213 lb.—on the Est; 199 lb. on the Ouest. The weight, in working order, ranges from $56\frac{1}{2}$ tons on the Midi, to $64\frac{1}{2}$ tons on the Est.

Three prominent points of merit have been instanced in the case of all these de Glehn compounds, viz.: (1) the provision for direct admission of steam to the intermediate reservoir; (2) a three-way valve by means of which the exhaust from the high-pressure cylinder can be discharged into the atmosphere, thus avoiding an excess of back-pressure; (3) the setting of the high-pressure and low-pressure cranks on each side of the engine at an angle of 162 degrees to each other, which renders the work of starting far easier.

The author has been referred to as an enthusiast in his admiration of French engines. This is an error in terms. It is his rule never to allow any enthusiasm or feeling to enter into his view of subjects which are purely scientific and practical. He regards them from an absolutely impartial standpoint. If a bare record of the work done by the French compound engines is so striking as to compel the enthusiastic admiration of those who read it, the recorder cannot be held responsible. All the more credit belongs to the engines that do such remarkable work. When the author started upon a course of observation of the performances of the French compound locomotives he was quite unaware either that the engines or their performances were of any special merit, and on his return to England he found that this want of knowledge existed also in the case of nearly all the leading engineers of this country. It came upon him as a surprise—and not an agreeable one—to find even three years ago that engines running in considerable numbers on the French railways were doing work that engines in Great Britain had never, in the author's experience, equalled or even approached. Take, for instance, his first trip. On that occasion one of the compound express engines designed by Monsieur du Bousquet on the de Glehn four-cylinder compound system, starting from Calais with a load of 20 coaches, weighing 260 tons, behind the tender, ascended the eight mile bank of 1 in 125 to Caffiers at a minimum speed of 41 miles an hour. In England he had found 36 miles an hour reckoned as a very high speed with such a load, even up a grade of 1 in 200, and here was a French engine exceeding that on a gradient nearly twice as steep.

Another revelation was the gradient profile of the French Northern Railway from Calais to Paris. It had been constantly described as a dead level

throughout—as flat as a table. Yet it appeared as a matter of fact that only a length of 60 miles out of the whole $185\frac{1}{2}$ was level, viz., that from Etaples to Amiens. The remainder formed four gables, the first having a continuous ascent for eight miles of 1 in 125—equal therefore to the Graywrigg bank on the London and North-Western, and steeper (on the average) than either that from New Cross to Halstead on the South-Eastern, or from Dover to Shepherd's Well on the London, Chatham and Dover, which are so often quoted as obstacles to great speed on the part of the English line. Next, after a corresponding descent, came between Boulogne and Etaples, a second gable of 1 in 135 up on each side; then after Amiens an ascent of 1 in 250 to 1 in 350 for 26 miles, and a corresponding descent to Creil; finally a 13 mile climb of 1 in 200 and a similar descent. This is worse than most of the English main lines, as a comparison of gradient maps will show. Yet that one line alone can show more fast booked times than all Great Britain has at present. The Orleans and Midi lines run the Nord close in speed, but, as a rule, have lighter loads, except in the case of one express each way. The Nord line, on the other hand, runs its remarkable speeds with heavy loads, yet maintains equally remarkable punctuality.

Generalisations in such matters are often misleading. It is irrelevant and useless to talk vaguely about French and English loads and grades, or to compare them as more or less steep or heavy. The author's method has been to note the working of engines with specific known loads and on specific known grades, and to make his comparisons on that basis solely. Thus, in observing the work of the four-cylinder compounds on the splendid train known as the Rome-Calais express, which was timed to run from Paris to Amiens, $81\frac{3}{4}$ miles, in 81 minutes, start to stop, or at an average speed of 60·5 miles an hour, he found that this was done easily within time with loads varying from 150 to 190 tons behind the tender, although two continuous banks, respectively of 1 in 200 for 13 miles, and 1 in 250 to 1 in 333 for 25 miles, had to be climbed. He found that with the heavy Lille and other expresses booked at start-to-stop speeds of 55 to 57 miles an hour those speeds were constantly maintained, and even improved upon, time being freely made up in case of station or signal delays. He found the engines able to maintain 55 miles an hour up banks of 1 in 250, hauling 270 tons, and 50 miles up 1 in 200, with a like load, each bank 13 to 25 miles in length being started at 10 or 15 miles an hour, owing to slacks for junction points. One engine maintained 43 miles an hour up the eight-mile bank of 1 in 125, hauling 280 tons. Another, starting at the foot of a 12-mile ascent of 1 in 200, with 340 tons behind the tender, attained 40 miles an hour in 2 miles and steadily gained speed until just before the summit the rate was 47 miles an hour; while up 1 in 250 a rate of 51 miles an hour was maintained, and that with a load of 340 tons exclusive of engine and tender. With lighter loads, such as 180 to 200 tons, speeds of 60 to 62 miles an hour were maintained up 1 in 200, and with 110 to 150 tons, 65 to 70 miles an hour.

It will thus be seen that the remarkable booked speeds were accomplished through the fine work uphill, for the prescribed limit of 120 kilometres, or 74·4 miles an hour, was rigidly adhered to in down-hill running, never being exceeded except on special experimental occasions and by express permission. In such particular cases the author has tested the speed up to 85 miles an hour, when the limit of the engine's capability was by no means reached; also at 75 miles an hour for many miles on the

level with a light load, so that no doubt exists as to speed capacity. But it is in the actual collar work uphill and on the level that the achievements of the engines of the standard class on the Nord, and notably those numbered 2.161 to 2.180 and 3.121 to 3.170, surpassed all others in the author's experience. In no instance was a pilot or assistant engine employed.

Yet even these achievements have been eclipsed recently by one of the two exhibition engines, specially constructed to Monsieur du Bousquet's design on the de Glehn system, for the Chemin de Fer du Nord. One of these was shown in the Vincennes Annexe, the other has run on regular services. The type differs from its predecessors in several respects besides that of augmented size. It is of the so-called "Atlantic" class, having a four-wheel leading bogie and a pair of carrying wheels behind the firebox, the two pairs of drivers being in front of the firebox and placed close together under the exact middle of the engine. The coupled wheels are 6 ft. 9 in. in diameter instead of 7 ft. The boiler is very large, being 16 ft. 8½ in. in length, or 13 ft. 9½ in. between tube-plates and 4 ft. 9½ in. in internal diameter. The total heating surface is 2,275 sq. ft., and the steam pressure is 228 lb. per square inch. The tubes are of the Serve pattern; the firebox is of the Belpaire design, giving 167 sq. ft. of heating surface, with a fire-grate of 29½ sq. ft. The two high-pressure cylinders, placed outside, are 13½ by 25¼ in.; the two low-pressure, inside, 22 by 25¼. The cranks are set at an angle of 180 degrees instead of 162 degrees as in the earlier types. The total weight of the engine in working order is 63 tons; of the eight-wheeled tender 45 tons. The adhesion weight is 33 tons, and the total of engine and tender 108 tons.

In an experimental trip with this splendid engine, the author found it able to take a train of 305 tons, exclusive of engine and tender, from Paris to St. Quentin, 95¾ miles, in 90 minutes 52 seconds, start to stop, averaging 62·1 miles an hour up the 13-mile bank of 1 in 200, and never going below 59·2 miles an hour, also maintaining 75 miles an hour on the level and slight rise, all these with a load of 305 tons behind the tender. No performance of equal merit had ever previously come under the author's notice. It should be noted that in descending down grades the speed was kept rigidly to the legal limit, 74·4 miles an hour, otherwise a still higher start-to-stop average could have been obtained.

It could hardly have been expected that such an achievement as this would have been surpassed by the same engine, but this actually happened within three weeks. The author was courteously invited by Monsieur du Bousquet to be present at a special trial of the engine, No. 2.641, with a load of no less than 365½ tons (French) or 360 English tons, which took place on the 13th October. The train selected was the famous Nord express from Paris to Cologne, Berlin and St. Petersburg, and the test was made on its first stage, viz., to St. Quentin, a distance of about 95¾ miles, which includes one bank of 1 in 200 for 13 miles continuously and another of 1 in 333 for 10 miles. With that enormous load of 360 English tons behind the tender—or 468 tons if the weight of engine and tender were included—No. 2.641 ascended the 13 miles of 1 in 200 at an average speed of 56 miles an hour, the lowest speed point being 52·2, while on the latter part of the rise the rate was as much as 57·1. On the length of level and slightly rising grades from Creil to Tergnier, a steady rate of 64 to 70 miles an hour was sustained. Tergnier, 81¾ miles from Paris, the same distance as Amiens, was passed in 80 minutes 44 seconds from the start,

but thenceforward as the train had got materially in front of its booked time, although two signal checks were encountered, the driver unfortunately had to ease down, nevertheless the train came to a signal stop just outside St. Quentin station in 96 minutes 13 seconds, from Paris, the final stop inside being in 97 minutes 31 seconds, in spite of signal delays totalling $2\frac{1}{2}$ minutes.

Another feat consisted in taking the Paris-Calais corridor dining train up the eight-mile bank of 1 in 125 between Calais and Boulogne at a minimum speed of 52 miles an hour, and subsequently up the 26 miles of 1 in 250 and 1 in 333 at a minimum rate of 65 miles an hour, the weight being 267 English tons behind the tender; while in the opposite direction, with a 235 ton load, the 23 miles of 1 in 250 and 1 in 333 were ascended at 65 to 68 miles an hour, and the Caffiers incline of 1 in 125 was actually climbed at an average of 61·8, the absolute minimum being 55. In a special down-hill test, the engine also attained 85·8 miles an hour, so that its swiftness is unimpeachable. These achievements appear to the author so remarkable as to be almost phenomenal.

A few engines of the Vauclain four-cylinder type and also a few of the Mallet two-cylinder compound type are at work in France, the former on the Etat line, but the author has had no opportunity yet of personally observing their performances. The de Glehn system, as already stated, has now become the standard for all France.

In Great Britain three experiments have been made with four-cylinder compound locomotives, built on the tandem method. One was a rebuilding of the identical North British engine which fell into the sea on the occasion of the Tay Bridge collapse. On being raised after many months' submersion, it was converted into a tandem compound, but with unsatisfactory results, so the engine was reconverted to the non-compound type. On the Great Western two locomotives were constructed on the tandem principle. Both had 7 ft. coupled wheels and four cylinders, all inside, the low-pressure cylinders in each case being placed in front of the high-pressure pair. One of the engines had 14 in. high-pressure cylinders, and 22 in. low-pressure, and the other had 15 in. and 22 in. cylinders respectively. In the former case each of the low-pressure pistons had two piston rods, one near the circumference of each piston and fixed so as to pass on either side of the high-pressure cylinders, behind which they were connected with one crosshead, as also was the low-pressure piston rod. Thus each crosshead was actuated by three piston rods, and the engine had six piston rods altogether. The experiment was interesting but not successful, and the engines were condemned.

A somewhat similar arrangement is used on twenty eight-wheel coupled goods engines of the Chemin de Fer du Nord which are built on the tandem four-cylinder compound principle, and which are stated to do very efficient work. One three-cylinder compound engine with six coupled wheels and a radial leading axle has also been tried on the Nord line. In this case there is one high-pressure cylinder inside and the two low-pressure cylinders are placed outside the frames. No particulars of this engine's work have so far been procurable.

Two isolated types of three-cylinder compounds have also been tried by British designers. One case is that of a North-Eastern 7 ft. coupled express engine built on the Worsdell-von-Borries system. This has been re-built as a three-cylinder compound with a single 19 by 26 high-pressure cylinder inside and two 20 by 24 low-pressure cylinders outside. In several

experimental trips, the author found it do excellent work, pulling heavy loads and attaining high speeds, but the type has not been multiplied. The other instance, although emanating from a British designer, Mr. John Riekie, Chief Mechanical Engineer of the East Coast of India Railway, and tried in British territory—viz., in India—has not yet been seen in the mother country. Mr. Riekie's system consists in retaining the two full-sized high-pressure cylinders of a non-compound engine, and adding a third, or low-pressure cylinder, these cylinders acting on three cranks set at angles of 120 degrees. The ratio of the combined area of the two high-pressure cylinders is to the low-pressure cylinders as 1 to $1\frac{1}{4}$, instead of 1 to 2 or $2\frac{1}{4}$ as in the case of most other compound types. One great difference between this system and all its predecessors consists in cutting off steam early in the two high-pressure cylinders, in place of a late cut-off in one or two smaller high-pressure cylinders, also in adopting a new departure in low-pressure cylinder ratio to suit this early cut-off. The cranks are so balanced that all revolving parts are balanced in a vertical plane. The inventor claims that both a wider range of expansion is obtained by his method, and also that a greater reserve of power is retained. He contends that he gains 30 per cent. more power by his plan; that it is capable of modification so as to give 60 per cent. more power than the largest that can be got out of cylinders with existing methods; and that owing to the possibility of vast increase in cylinder dimensions, larger driving wheels could be used and piston speed thus be diminished. According to the records taken of the performances by two Indian engines constructed upon this system, it appears to be very efficient in operation and to possess much promise of future success. It is to be wished that it should have a fair trial in this country, but as the author has had no personal experience of its work, he is, of course, unable to offer any definite opinion, save on theoretical grounds, as to its value, which he is disposed to rate highly.

Summing up, in conclusion, the results to which the author has been conducted by his fifteen years' personal observations of the working of compound locomotives, he feels no hesitation in declaring that the four-cylinder compound must almost of necessity be the standard locomotive of the future in Great Britain, as it is of the present in France. He is not entirely satisfied that the limit of extension permitted by the British loading-gauge has yet been reached in the case of simple high-pressure or non-compound engines, even by Mr. J. A. F. Aspinall's Lancashire and Yorkshire giants of the 1·400 class, or by Mr. Wilson Worsdell's ten-wheeled 2·001 type. Smaller wheels than 7 ft. 3 in. in the former case and larger boilers in the latter would permit yet further increment of power were this deemed desirable, but it is questionable if that could be accomplished with economic advantage. On the other hand, compounding enables the same steam to be profitably used twice over, and also to be first employed at a higher pressure than would be economical were it to be exhausted after doing duty but once. In this way large economy of power can be obtained, consequently more power out of a given quantity of steam and of the material consumed in its generation and within limited dimensions. But to attain these results in the largest degree, the author holds it essential that four cylinders should be employed with ability to use high pressure in all four cylinders at starting or in case of emergency—as in the de Glehn compounds—and that the driving wheels should be coupled.

As to the relative merits of the various cylinder positions or of the several rival systems of four-cylinder compounding, the author does not consider it needful to express any opinion. He has deemed it preferable to record his own experiences with the systems used in England and France, and to indicate the conclusions to which those experiences have conducted him.

The question has been treated mainly in reference to what is, perhaps, the most important department of locomotive duty—the haulage of heavy express trains. But it may be added that the profitable employment of compound locomotives appears to be virtually limited to that class of service and to goods traffic having long runs without stop. In the latter class of work Mr. Webb and Mr. Worsdell have for some years employed very powerful compound goods engines, and, it is stated, with distinct advantage, while Monsieur du Bousquet's compound goods engines on the Chemin de fer du Nord and his ten-wheeled de Glehn compounds of the 3.121 class for fast goods trains have done excellent service, one of the latter having hauled a train of 1,014 tons at 38·5 miles an hour on the level and slightly rising gradients, at 21·1 miles an hour up 1 in 200, and at 23·4 miles an hour up 1 in 333; also 876 tons at 26·6 miles an hour for 23 miles up a grade of 1 in 200. But in this department of traffic the author has had smaller experience with compound engines, and he therefore prefers to say little on the subject, as he cannot speak with full personal knowledge. The application of compounding to engines working trains that have frequent stops he entirely disapproves, and the experiments tried by Mr. Webb in this direction have apparently justified that unfavourable opinion. The true function of compound locomotives is to take trains that run long distances without stoppage.

It may reasonably have been anticipated that the author would touch on the important questions of relative fuel consumption and relative cost of repairs in compound engines as compared with the non-compound types. He has not done so for the simple reason that no information is available that appears to him satisfactorily conclusive. He was a deeply interested and, he might add, highly amused, listener to the animated discussion which took place on this head among some of the most eminent of British engineers at last year's conference of the Institution of Civil Engineers. In view of the amazingly discrepant, utterly contradictory, and wholly irreconcilable statistics put forward on that occasion by some of the most distinguished authorities, he prefers not to be citable as being among those who "rush in where angels fear to tread."

WHAT IS A CIVIL ENGINEER?

By FREDERICK J. ROWAN, A.M.Inst.C.E., M.I.E.S., etc.

THE persistence with which habits, and especially bad ones, cling to us is proverbial, but it is doubtful if anything else can account for the slow progress which is made in stemming the perversion of the term "Civil Engineer." The parent institution has for many years given out no uncertain sound upon this subject, and the addresses of such men as the late Sir William Anderson, Sir Benjamin Baker, and more recently Sir William Preece, are so pointed and convincing that the only wonder is that any intelligent person can be found who harbours a different view from that which such authorities endorse.

Still, the fact remains that there are to-day many who cling to the idea that no one is a civil engineer who is not occupied with the designing or construction of such works as roads, railways, canals, docks, harbours, waterworks, river improvements and the like, and that those who are practised in the design and construction of ironworks, steel works, gasworks, chemical and other works, textile manufactories, engines, boilers, machinery, furnaces, ships, locomotives, and so on, are mere "mechanical engineers," creatures of a different and of a lower order.

It is easy to understand how this idea arose. In the days when Smeaton first adopted the term "civil engineer," the meaning was perfectly clear. The civil engineer was a man engaged in designing and constructing works or structures for civil purposes. Before his time, the engineer had done analogous work for military purposes, and the prefix "civil" differentiated the two classes. "No work," said a writer in "Engineering" some years ago, "came amiss to the old military engineer. Not only would he design and build a fortress or an earthwork, but he could construct a pontoon, bore a cannon, improvise a petard, and mend a broken scaling-ladder. He was not merely a man of science, learned in fortification, and an authority in mining, but he was also an able mechanic, and often attained wonderful results from very meagre and unlikely materials. Those who adopted his title implied that their sphere was, at least, as wide as his, with the exception of the purely military portion." In these early days, however, the proportion and importance of such works as roads, canals, bridges, harbours, etc., was greater than that of those which eventually outstripped them in extent when once the steam engine arrived. Consequently the title "civil engineer" became early associated in the public mind with a certain arbitrary division of engineering work. Not only so, but also a considerable section of the profession took a restricted view of the duties of the civil engineer, and "confined the appellation to those who practised in building and earthwork construction, such as roads, railways, harbours, docks, river improvements and so on. Civil engineering, in fact, became a branch or section of engineering proper, and ceased to include the whole field. There

was a limitation—almost a degradation—of the meaning of the term." I am indebted to an article in "Engineering" (*i.e.*, the journal of that name) for some of these apt expressions of what I desired to convey, and I make a further quotation from the article in order to emphasize a salient point, which, however, is not often noticed. "For a time the institution was in practice, although not in theory, in league with those who accepted this narrow view of the capabilities of a civil engineer. It elected quite readily any man who had been engaged in the construction of railways, docks, and the like, but gave only a grudging welcome to those who designed and manufactured machinery. This was, however, but a temporary lapse. It is quite opposed to the Charter of the Institution, which commences, 'Whereas . . . certain of our loving subjects have formed themselves into a society for the general advancement of Mechanical Science.' Evidently men skilled in mechanics could not be properly excluded from a body formed for the advancement of mechanical science, and the institution, realizing this, has for many years received engineers following any branch of the art, and has expressly laid it down that they are all civil engineers, provided their work is not for military purposes."

Perhaps the lingering influence of former prejudice is sometimes even yet to be discerned in the disinclination, evident in some quarters, to admit certain classes of engineers to the full dignity of M.I.C.E. In the interests of the profession, it is to be hoped that even this will soon pass away.

The comprehensive and far-seeing definition of a civil engineer, which is due to Tredgold, is embalmed in the charter of the institution, and, from the frequency with which it has been of late years quoted, is no doubt familar to all engineering students. Sir William Preece's quotation of it, in his able address "On the Functions of the Engineer," is so recent that I need only refer any one seeking information on this point to that address.

The candidate for admission to the American Society of Civil Engineers is required to have the "ability to design, as well as to direct, engineering works," but whilst this gives a useful prominence to what forms a distinguishing mark of an engineer as contrasted with a contractor or a mechanic, it really adds nothing to Tredgold's definition. "The art of *directing* the great sources of power in nature for the use and convenience of man," necessarily includes the ability to *design* the works or apparatus which the practice of that art demands, and it follows obviously that those who execute or carry out the plans made for them by another need not possess—although many who do so undoubtedly do possess—the ability to devise such plans.

To direct the great sources of power in Nature demands an intelligent acquaintance with these powers and their range of action, and with the laws which underlie the various phenomena due to them, because all intelligent use of them must be governed by obedience to these laws.

It seems to me to be essential to our subject that we should raise the question, "What are the sources of power in Nature?" It would perhaps be more correct to say, "What are the forces of Nature?" for there can be only one *source* of power in Nature, and that is the energy of its Creator. The forces of Nature, which become by intelligent use sources of power to mankind, become known to us through phenomena, which, on account of their invariable character, have led to their immediate causes being termed "natural laws." It is, however, becoming increasingly apparent that they are, one and all, manifestations of one all-pervading natural principle, which is a never-

ceasing molecular activity. Some of these forces are well known. Gravity, cohesion, chemical action and affinity, light and heat, atmospheric pressure, evaporation and condensation, wind, water falling and flowing, the tides, atmospheric electricity and terrestrial magnetism, have long been familiar almost as household words; but the most truly universal of all, viz., molecular energy, is only as yet but dimly discerned, and feebly grasped.

These may be regarded as the *elements* in our science, because they are primary natural conditions or actions. What we may consider as derived conditions, and so corresponding to *compound* or *derived bodies*, as in chemistry, are fire or combustion with flame, the expansive force of steam and other gases, pneumatic pressure, hydraulic pressure, and produced electricity and magnetism. These are the forces of Nature with which we as engineers have to deal, and in order to study or to utilize them, we must obviously be acquainted also with the nature, qualities, and strengths of materials.

By acquaintance with the action of these forces, we learn that several of them have a common origin, and we find, for instance, in heat, its increase, transference, and abstraction, the source of many phenomena which are essential to the comfort and convenience of man. Evaporation and condensation producing rain, waterfalls, and streams; currents of air producing wind; the expansion and contraction of solid bodies; the change of physical state, through solid, plastic, liquid, gaseous, or *vice versâ*, not forgetting the importance of this as applied to the liquefaction and solidification of gases hitherto considered permanent; the expansion or dilation of gases, not omitting the effects denominated explosive; and the disintegration, whether physical or chemical, of many substances, are among the proofs that in heat is found "a great source of power in Nature."

Similarly we learn that light is responsible for many actions, chemical and physiological, beyond the primary one of illuminating, and so enabling us to see what is above, beneath, and around us; and in electricity we have found a form of energy capable of giving rise to a marvellous variety of actions and results.

Of late years, as I have indicated, another great generalization has been emerging from the region of speculation into the broad light of well-ascertained fact. The expansion and contraction of metals under the influence of heat and cold probably first aroused inquiry into the nature of the movement which was thus observed. The transmission of light and heat, and, as now proved, electricity also, from the sun through vast distances containing no mundane atmosphere, has been (since the days when the idea that heat is a substance was laid aside in favour of the vibratory theory of light and heat) a fruitful means of enlarging the understanding of men as to the kind of motion which must pervade the universe. Similarly the study of the nature of electricity and magnetism, and of the transmission of electricity along wires, or, more recently, without wires, and inquiry into the inherent difference between conducting and insulating substances, have tended in the same direction. So also has the knowledge of the production of heat by friction and percussion, which, in itself, led directly to the understanding of the conservation of energy, and to the mapping out of a well-defined mental territory under the name of thermo-dynamics.

Many years ago Thomas Graham, the celebrated master of the Mint, taught that the three conditions of matter, gaseous, liquid, and solid, probably exist for every substance, although one condition predominates in each case over the others, and that solidification may not, therefore, involve the suppression

of either the atomic or molecular movement, but only the restriction of its range. The labours of such men as Andrews, Dewar, Pfeffer, Van't Hoff, Ostwald, Professor W. Spring and Sir W. Roberts-Austen, who have followed up Graham's teaching by experimental investigations of a brilliant character, have proved to demonstration the truth of his views, and the persistent molecular unrest of solids and liquids no less than gases. And the unique researches of Sir William Crookes, combined with Professor Röntgen's remarkable discovery and demonstration of the X Rays (which may be considered as in great degree the outcome of the former researches), have crowned the work by giving us an insight into, and a grasp of, the truth of molecular energy never before realised. The Röntgen Rays have already proved, in a high degree, that there are means of directing in a new way that source of power in nature for the use and convenience of man; and that further great practical results are possible is indicated by the following words from Sir William Crookes' Presidential Address to the British Association in 1898:—

"The total energy of both the translational and internal motions of the molecules locked up in quiescent air at ordinary pressure and temperature is about 140,000 foot pounds in each cubic yard of air. Accordingly the quiet air within a room 12 ft. high, 18 ft. wide, and 22 ft. long, contains energy enough to propel a one-horse engine for more than twelve hours. The store drawn upon naturally by uranium and other heavy atoms only awaits the touch of the magic wand of science to enable the twentieth century to cast into the shade the marvels of the nineteenth."

If any one is tempted to think that these are matters beyond the ken of the civil engineer, as such, I would ask him to consider the enlightened and extensive view of the functions of the engineer enunciated by Sir William Preece no later than in February of this year. We may, in fact, advance further in our appropriation of natural forces, for not only do we find in the marvellous extent and activity of infusorial life a natural force which is capable of being directed for the use and convenience of man—as is instanced by the system called the bacterial treatment of sewage—but we may also learn that living force is capable of being utilized in other directions and by other methods, as the investigations of telepathic phenomena are surely, if slowly, proving. If Sir William Crookes' explanation of these, founded upon the facts of ether vibrations and on the analogy presented by wireless telegraphy, be correct, the vibrations produced in the brain and nerve cells of one person may undoubtedly be transmitted to, and recorded in, corresponding cells, amenable to the same frequency of vibration, in another. This may, at any rate, be of interest to us as engineers, because it has been urged more than once that to be a successful engineer one must be able to direct the minds of men—to manage, or, as it has been put, to "handle corporations both public and private as if they were machines"; and if this is a necessary means to success, we may find in telepathy a scientific method of developing it! Whatever may be the fate of this suggestion, I would like, in all seriousness, to commend to your notice some of the weighty words found towards the close of Sir William Crookes' address at Bristol, in which, in opposition to the materialism of those who, like Tyndall, tried to "find in *matter* the potency and promise of all terrestrial *life*," he declared that he preferred to reverse their apophthegm, and to say that *he* "found in *life* the promise and potency of all forms of *matter*."

It is possible, on such an occasion as the present, only to take a rapid glance

at these great subjects; but I have ventured to do so because we are apt to think more of our works than of the forces which we are the mere instruments of directing into useful channels. Whilst not in any degree undervaluing the importance of practical work, it is imperative that engineers should know not only the names of these forces, but also something of their nature, the range of their action, and the laws which they illustrate or embody. It is our business, as well as our high privilege, to make an intelligent use of them. To deal intelligently with steam or heat engines demands acquaintance with mechanics, thermo-dynamics, chemistry and physics. The intelligent consideration of even the design and working of a steam boiler brings us into contact with Pascal's law of fluid pressure, Boyle's and Mariotte's laws concerning gases, the laws of chemical combination, and of the conduction and transference of heat, besides some elements of hydraulics and of metallurgy.

It has been said truly that whilst a clever sewer builder might design a drain and claim to be a sanitary engineer, yet only the man who approaches his work with an intelligent knowledge of the conditions which sanitation involves could, in that department, be a civil engineer. And so in other departments also, it is really the possession of scientific knowledge which differentiates between the engineer and the artificer.

The same talents are required in all departments of engineering work, and the same knowledge of natural phenomena and laws. The specialised part of any engineer's equipment is found in his knowledge of the particular service or process for which a building, or a machine, or other work is wanted. But it is not good to specialise too exclusively, for it is easy to become buried in a groove. The history of invention, moreover, has shown us that great improvements are most frequently due to men whose vision is not confined to the narrow limits of one branch of practice. The great civil engineers and inventors of past days illustrate this, for Smeaton was educated for an attorney, and taught himself engineering; Watt was a philosophical instrument maker, and Stephenson a colliery engine keeper; Murdoch was a miller and millwright, Bessemer, a pattern designer and student of chemistry, and Pullman was a cabinet-maker.

I must confess that, in the light of such facts as those which we have had in brief review, I find it difficult to understand on what possible grounds the man who makes, surveys, and designs the plans of a railroad, should be considered a specimen of a higher type of engineer—*the* civil engineer *par excellence*—whilst the man who designs and makes the locomotive and rolling-stock, or the man who designs electrical apparatus, from the massive dynamo to the delicate magnet operating signalling and telegraph apparatus, should be relegated to an inferior class, and be considered as "only a mechanical engineer!" Lest any one should think this a fanciful idea, I may say that I quote from a remark made to myself in this room, and it is certain that the words and actions of some show that to call a man a mechanical engineer is equivalent, in their estimation, to placing him in a lower class than their own. This may be due to their inability to understand the full bearing and importance of mechanical science, and, if so, it is obvious that it is they who are not in sympathy with the aim of the parent institution.

One cannot but wonder whether they remember that it was the invention of the locomotive that called the railway system into existence, and that the designer of the first efficient locomotive

was himself also one of the first and greatest designers and builders of railroads. Surely in this case, at any rate, the order of precedence which exists in the minds of these engineers to whom I allude has been subject to an unfortunate dislocation, or, as the French would term it, *bouleversement!* There is, I can admit, one aspect of the subject under which they have the appearance of being in the right; and that is, that as the engines and vehicles must run on the road, and suffer damage if they leave its guidance, those who construct that road can *in this sense* claim to be *directing* one of the sources of power in nature for the comfort and convenience of man, that is, of those who are travellers by it. If we consider navigation, its enormous indebtedness to, and even dependence upon, mechanical science must be admitted. But for the slighted "mechanical engineer," where would be the supply of the material from which alone ships of the present dimensions could be built; where the machinery without which they could neither be propelled at high rates of speed, nor worked when under way or in port—where, in fact, and what, would the ships be? And what do harbours, docks, lighthouses, and such works owe of their present importance to the existence of steam navigation?

The major part of experiments on the tensile and other strengths of metals, and on the effects of differences of temperature and of corrosion on various materials, have been carried out by men engaged in making engines, boilers, and ships. We may ask, are tests and the resulting calculations of strength of materials as applied to such structures of less importance to engineering than those which are applied to the same materials when used for bridges, roofs, and girders?

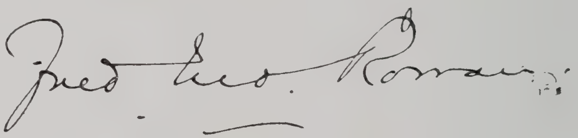
Few of the sciences could make headway in investigation and research without instruments and apparatus due to mechanical skill, and none of the manufacturing processes, whether metallurgical, chemical, or textile, could exist without machinery. Not only so, but also surveying, mining, canal cutting, harbour building, dock construction and the numerous works supposed to be the exclusive birthright of the fancied higher grade of engineers, would have a sorry chance of being carried out on a scale of any magnitude but for the assistance of the appliances emanating from the supposed lower grade.

I can go a step farther, and say that it will not be denied by any one competent to form a judgment on the point, that there are few properly trained so-called "mechanical engineers" who could not design and construct a bridge, or a railway, or a dock, or almost any other engineering work, if called upon to do so.

Having said thus much, with the purpose of trying to give an unworthy prejudice its quietus, I wish to urge upon you that there should be no question of jealousy or of rivalry (except of a friendly kind) between different branches of engineering. We must admit that the modern locomotive is a masterpiece of mechanical science, and that the railroad exhibits many of the crowning triumphs of engineering skill, and we must maintain that it is the same science of engineering which has produced both. The time is approaching when all petty distinctions between different sections will lose their importance, and the different titles attached to such sections will sink into insignificance before the important one of engineer. Even now, as may be seen by a survey of the table prepared and exhibited by Sir William Preece, which, by his courtesy, I am enabled to show to you

this evening, it is impossible to draw any sharp line of division between any two of the great branches of engineering, not excepting the military one, for the work of one branch merges at several points into that of another.

If we have—and this is the important point—a proper conception of the dignity of the profession and the vast sphere of operations in which one and all of us are but instruments, we shall have no need to resort to any expedients for maintaining our own particular dignity, or that of the branch in which our work more immediately lies; and we shall not grudge to any the attainment of excellence in their own place in that sphere. However long a life we may spend in its service, to the end of that span we can never be other than students in so profound and far-reaching a science, and there is no reason why we should not prosecute that study in a right spirit as regards our attitude both towards our subject and towards all our fellow-students.

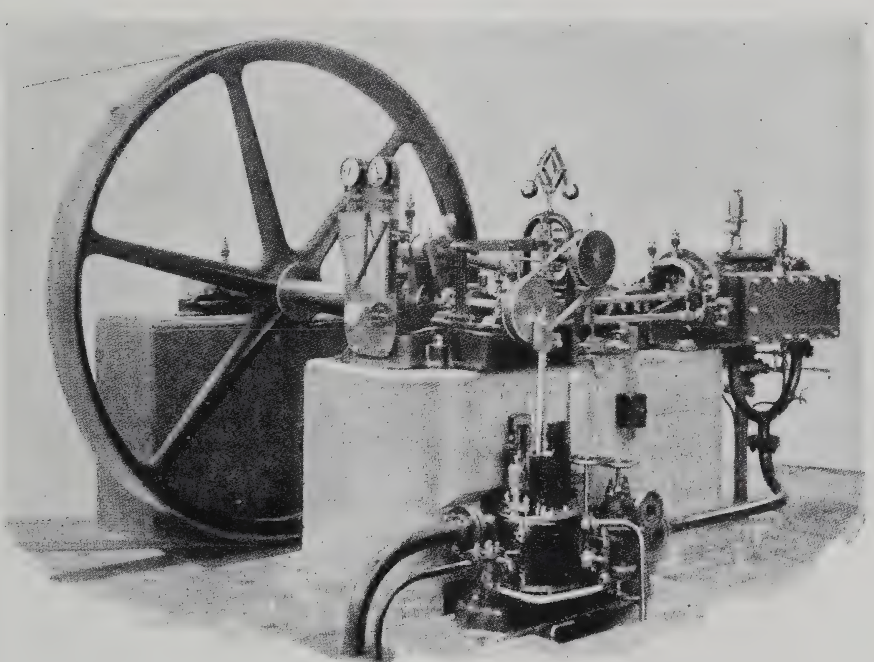


NEW MACHINERY, APPLIANCES, ETC.

(Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.)

THE PIGUET ENGINE.

WE illustrate a 25 h.-p. Piguet steam engine exhibited at the Paris Exhibition. It has a cylinder diameter $7\frac{7}{8}$th in. and a stroke of $15\frac{3}{4}$ in., and runs at a speed of 180 r.p.m. It is provided with a main valve and a cut-off valve working in the ordinary manner on a flat seat. The makers, Messrs. Piguet & Co., also exhibited a 600 h.-p. engine of similar design. As our readers are probably aware, these valves one only expects to see in engines of small power, but the manufacturers assure us that the advantages of this construction outweigh the disadvantages, and continue to use them exclusively with a single cylinder.



A 25-H.-P. PIGUET ENGINE.

ENGINEERING NOTES.

WE learn that Messrs. Graham, Morton & Co., Leeds, have obtained a contract for the Edinburgh and Leith Corporations Gas Commissioners, amounting to the sum of £113,802, for the erection of a complete automatic

inclined retort carbonising plant, including their improved system of elevating and conveying machinery for handling coal.

* * *

The 1901 Catalogue on their dynamos, motors, transformers, switchboard and switches reaches us from the Newton Electrical Works, Limited, of Taunton, and includes some practical hints on the management of "Taunton" dynamos. These "hints" are worthy of a careful perusal, as they embody much useful information in a concise form.

* * *

Messrs. Blackstone & Co., Limited, of Stamford, have recently brought out an interesting booklet on their oil and gas engines, which gives particulars of their sizes, prices, and system of working.

* * *

Messrs. David Bridge & Co., of Castleton Ironworks, Castleton, near Manchester, have just issued a pamphlet descriptive of their friction clutches, and containing some testimonials from users, amongst whom we notice some of the leading manufacturing firms. Messrs. David Bridge & Co. have now more extended facilities for executing large orders, having moved into new works at the above address. In an early issue we hope to give our readers some particulars of the works and their equipment.

* * *

The Simplex Steel Conduit Co., Limited, of Birmingham, forward us their supplementary list, and draw attention to their new screwed brazed conduit of heavy gauge and screwed fittings for use in places such as breweries, etc., where a watertight system is insisted upon; split bends and tee pieces; a new type of box, enamelled, iron-cased switch and fuse distributing boards; pendant fittings with porcelain bridge, with connection terminals fitted; also split box with bridge terminals and a connection box for connecting up branch circuits from a pair of bars fitted on to porcelain in the box; removable porcelain interiors and connection bars for use with their standard junction boxes. This arrangement consists of a porcelain cradle, which just fits inside the junction box, and supports two brass connection bars, which are each made in two parts. The bars are drilled along their length, and terminal screws are fitted to clamp the branch circuit wires, and a half-lap joint in the middle allows the two ends to be easily sweated on to the main lead, it being thimble bored to receive same. A large variety of T jointing boxes are also listed, with a number of special junction boxes, etc.

* * *

From the Campbell Gas Engine Co. Limited, of Halifax, who are making extensive additions to their works, comes an instructive book on their productions, which include gas and oil engines, and combined sets of these engines directly connected to different types of pumps, which the Company now also supply. The list is most handsomely illustrated.

* * *

The most handsome Christmas number of a trade publication that we have seen is that of *Milling* — the leading weekly organ of the milling trade. It contains, amongst other good things, a review of Milling in the last year by E. R. Voller; an article on "The Milling of the Future," by Felix Holt; "Handling Grain in Bulk," "Wheat Vitality," by W. G. Anderson; "The Law Cases of the Past Year," "A Holiday in the Canary Islands" (beautifully illustrated), etc. These are good things, which up-to-date millers should not miss. The price of the issue is 1*s*.

NEW PATENTS.

(Selections from recently published Patent specifications. Complete copies may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, W.C. Price 8d. each.)

No. 318. "Axle Boxes for Locomotives and other Railway Vehicles," A. Spencer, of 77, Cannon Street, London. Dated January 5th, 1900.

The lubricant receptacle or each such receptacle in the top of the axle-box is provided with an upwardly extending rim flange or seat, to which is fitted a hinged or pivoted spring cover, the seat and cover being so relatively formed and arranged that rain and dirt cannot pass between the two and enter the lubricant receptacle, but so that the cover can be readily lifted up when it is desired to inspect or re-charge the lubricant receptacle.

* * *

No. 13,236. "Screw and Bolt Heads," F. W. Rodd, of 124, Hawthorne Street, Cleveland, Ohio, U.S.A. Dated July 23rd, 1900.

The screw or bolt head has a flat bottom and is circular in cross section from top to base. It is provided with a series of shoulders extending from the base of the head upward, deepest and widest nearest the base. The head is also provided with a series of flutes at regular intervals from the top of the head downward substantially parallel to its axis, and across the bottom of each flute is a web constituting a part of the otherwise flat bottom of the head.

* * *

No. 14,127. "Shoots for Grain, Coal and other Material," A. J. Boult, a communication from G. E. Green, of 17, Frederick Street, Binghampton, N.Y., U.S.A. Dated August 7th, 1900.

The chute consists of two or more sections, each of which is tapered longitudinally or reduced in width from one end to the opposite end and is provided with sockets formed in its sides at its wider end, the narrow end of one section extending into the wider end of the next section. A rod extends across the lapped ends of adjacent sections, and its ends fit in the said sockets formed in the sides of the outer section.

* * *

No. 14,366. "Friction Ratchet Devices," H. John, of Pilse, 8, Erfurt, Germany. Dated August 10th, 1900.

This invention relates to a coupling or transmission device for coupling the driven parts of power machines or engines to the driven parts, and is characterised by an operating or driven shaft to which a comparatively slow rotary movement is given by a rapidly rotating main or driving shaft. The coupling is effected by friction produced by a one-armed lever, one end of which has an aperture or eye which surrounds the driven shaft. This friction is produced by the wedging action of an intermediate device, which presses almost radially against the driven shaft, as the lever oscillates, in such a manner that the effective component force of the wedging device causes one half of the eye of the lever to exercise a great pressure against the driven shaft, in consequence of which pressure and the friction thus caused by the oscillating lever the said driven shaft is forced to participate in the movement of the lever, in one or the other direction. In this manner the driven shaft is coupled with

the lever in one direction of the movement of the latter.

No. 15,340. "Apparatus for filtering Feed Water for Steam Boilers," H. Schmidt, of 64, Herderstrasse, Hamburg, Germany. Dated August 28th, 1900.

The apparatus consists of conical metal plates or "dishes" arranged in a casing and furnished with inlet and outlet openings, between which metal "dishes" the filtering cloths are arranged, the distinguishing features being that the feed-water to be filtered only passes through the filtering cloths in one direction, and the sludge blown away from each upper filtering cloth, when the filtering cloths are cleansed by means of steam, can flow away freely on the conical metal "dishes" without coming on the filtering cloth lying next below.

* * *

No. 15,375. "Processes for Pressing Articles from a Brass Alloy," G. Heinze, of No. 1/2 Pflugstrasse, Berlin. Dated August 29th, 1900.

In this process for producing articles pressed from brass alloy in moulds after the metal has been heated to a moderate red glow, blanks of a thickness and diameter corresponding substantially to the article to be produced are cut from bar brass, the said blanks being advantageously treated in the opposite direction to that in which the bar was produced, the articles being pressed in the moulds, which may be provided with suitable cooling channels or the like.

* * *

No. 15,807. "Turn-Tables for Locomotive Engines," N. Clegg, of 44, Trevelyan Street, Eccles, Lancaster. Dated September 5th, 1900.

Means are provided for the turning or operating of turn-tables for locomotive engines by steam supplied by the engine after it has been run upon the table. One or more, preferably two, steam cylinders or engines are applied to the turn-table and connected by friction clutches and spur gearing with a fixed spur ring attached to the base of the supporting pedestal whereby the turn-table may be rotated.

* * *

No. 21,237. "Method of Perforating Solid Metal Blocks," W. P. Thompson, a communication from The Hernadthaler Ungarische Eisenin-dustrie Actien Gesellschaft, of 8, Operngasse, Budapest, Hungary. Dated October 24th, 1899.

A block of metal is placed in a cylinder serving merely as its guide. A swage is fixed in front of the cylinder and placed axially with regard to the latter. The metal block is forced against the swage by means of a presser operating at the back of the metal block and guides in the said cylinder. The swage meeting the metal block, forces itself into the metal, thus expanding the metal in such a way that finally the solid block of metal is transferred into a tube having a cylindrical hole, which tube envelops the swage without the use of a matrix in the usual manner to limit the sideways motion of the metal or influence its outer form. It is preferable, when the blocks are worked hot, in order to prevent them cooling too quickly or unequally, to surround the swage with a cover, which prevents the access of air to the metal, but this cover does not operate to give form. The tube is then drawn off the punch and subjected to further operations as required.

* * *

No. 23,413. "Construction of Dynamo-Electric Machines," M. H. Robinson, of Overslade, Rugby, and M. H. P. R. Sankey, late Captain R.E., of Bawnmore, Bilton, near Rugby. Dated November 23rd, 1899.

The dynamo shaft is entirely dispensed with by casting a prolongation upon the spider or boss carrying the revolving part of a dynamo-electric machine which, being accurately turned, serves as a journal in the bearing at the end remote from the engine; the material for the casting is preferably steel.

THE WORLD'S TALLEST OFFICE BUILDING.

Height: 460 feet from domes to street. Contains 30 stories, divided into 1,000 offices.

The Engineering Times.

Vol. V. FEBRUARY, 1901. No. 2.

Queen Victoria.

BORN MAY 24th, 1819. DIED JANUARY 22nd, 1901.

✣ ✣ ✣

THE Victorian Era has closed. Victoria the Great has passed away. The most glorious reign in history has ended,—a reign which will equal previous centuries in progress and advancement. Our late Queen loved peace and its arts, the truest welfare of a people. A friend of the scientist, the inventor, the engineer, the manufacturer and the trader, her beneficent rule has given to Englishmen superior conditions of life to those enjoyed by the subjects of any other nation. From the throne of Victoria there radiated a splendid influence for good—an influence that made itself evident in English home life. Generations to come will know and appreciate the blessings that follow the reign of a good woman. Though the burden of her latter days was heavy, her good life brought a great reward, for there was no land under the sun, no nation, race or creed that did not join in the daily fervent prayer "God save the Queen."

✣ ✣ ✣

That Water-tube Boiler Committee: Is it to be Reconstituted?

Does Lord Selborne desire to get at the truth of the Water-tube Boiler question? Judging from the constitution of this Committee, the engineers of this country certainly believe that Mr. Goschen did not. Not that the Committee is deficient in men of unimpeachable character, but it does not possess the necessary qualifications to carry out satisfactorily the difficult work it has undertaken—and this for the following reasons:—

(1) With the exception of the Naval Engineer member, not one member has had any practica experience either of working or of making water-tube boilers of any design.

(2) All of the members, excepting the naval men, have duties which demand their first and close attention, and which they cannot afford to sacrifice in favour of this appointment.

As a writer to the *Pall Mall Gazette* recently pointed out, engineers in this country doubt whether a thorough investigation is really desired by the Admiralty; or whether the object is merely to strengthen the hands of that department in the course which they have hitherto ursued.

What are the qualifications of the engineering members?

Mr. Milton, the chief engineer surveyor of Lloyd's Registry, may be supposed to have had the designs of water-tube boilers through his hands officially; but as his duties lie entirely within the mercantile marine, he can only have had official experience of the working of those examples which have been introduced into merchant steamers since his appointment to his post, and these are practically of the Babcock-Wilcox and of the Haythorn types. Professor Kennedy has made experimental trials of a Thornycroft boiler on land, and is no doubt well qualified to direct the systematic carrying out of experiments for obtaining quantitative results, if the conditions suited to such work are at his disposal; but he cannot be said to have any experience of the working of boilers under ordinary sea-going conditions.

The special experience of the naval engineer, which Mr. Goschen used as an off-set to the lack of experience in the other members of the Committee, resolves itself simply into experience of the Belleville boiler, which is practically the prisoner at the bar. It is probable, therefore, that he appears either as counsel for the prisoner or as holding a watching brief for the Admiralty. Mr. List and Mr. Bain are undoubtedly good men in connection with their special work as engineering superintendents of two important lines of merchant steamships, but it was admitted by Mr. Goschen in the House of Commons that neither has had experience in connection with water-tube boilers. Dr. Inglis is an eminent shipbuilder, but neither he nor his firm has had any of that special experience which is required, as far as is generally known.

It follows, then, that while these gentlemen may direct experiments and cause inquiries to be carried out, practical work must be eft in the hands of subordinates or the Admiralty staff.

Is this the kind of procedure to produce reliable results? We think not. We want to see on that Committee a few men of sound practical experience like Mr. J. G. Dunlop, of the Clydebank Works, and Mr. F. J. Rowan, of Glasgow. And until a few such men are appointed, the Committee will not carry its proper weight—at least, with engineers.

Nile Irrigation Works.

The history of the very extensive irrigation works being carried out Lower Egypt has already formed the subject of numerous articles in the daily

and technical press, and it is not necessary, therefore, for us to treat of them fully here. We reproduce, however, two interesting photographs relating to same from Sir W. E. Garstin's last report. The first is a view of the sluices from down-stream of the Aswan Dam, being constructed by Messrs. John Aird and Co. The other shows some interesting work which is being carried on, namely, the construction of stone "sadds" or temporary dams. Two of these are necessary in each place to allow of the area between them being laid dry by pumping, thus enabling the permanent dam to be built. But serious difficulties have to be contended with even in the building of "sadds," for the stream will often carry away stones of two to four tons weight. This difficulty is now partially overcome by enclosing numbers of stones in wire nets, and dropping them into place. But this is not entirely satisfactory, owing to the sharp edges of the stones occasionally cutting the wire.

VIEW OF SLUICES (FROM DOWN-STREAM) BEING BUILT IN CONNECTION WITH NILE IRRIGATION WORK.

The Future of the Refuse Destructor.

"The period of doubt and exaggeration, of controversy and failure, of absurd guarantees and poor performances is past, and refuse destructors have now entered a period of sober, useful performances."

In this spirit Mr. George Watson writes for our contemporary, the "Electrical Review," on "The Disposal of Refuse in the Twentieth Century." Though it cannot be said that there is anything very strikingly original in the article, it is, nevertheless, pregnant with facts, and forms an interesting and refreshing summing-up of the present position of the refuse destructor.

We quite agree with Mr. Watson's remarks on destructors working under a strong natural draught.

Undoubtedly the day of powerful chimneys has passed; moderate and comparatively low chimneys are now being used, and are in themselves a complete vindication of the destructor as the only final and sanitary means of disposal without nuisance. If nuisance was still inseparable from the destructor, the high chimneys of ten and twenty years ago would still be necessary. Mr. Watson is in error in stating that the "Horsfall" destructor at Hamburg is the largest destructor in the world. The "Thackeray" destructor at San Francisco, although only having thirty-two cells, instead of thirty-six as in the destructor at Hamburg, has a capacity for destroying 700 *tons of refuse per day*. The cells are probably the largest in the world, each having a grate area of 96 sq. ft.

With regard to the new arrangement in the destructor for the Strand Board of Works, for firing the refuse directly into the furnaces, Mr. Watson says that "the results of this arrangement have yet to be ascertained, but it is hoped that some pence per ton will be saved in the cost of feeding the furnaces." This is not very encouraging, and although we do not wish to throw "cold water" on sincere attempts to improve the destructor, we cannot hold that this is a good one. Having to drag refuse forward from the drying hearth or secondary grate on to the grate proper, from the bottom of a mass weighing several tons, entails considerable labour. From the sanitary point of view, also, the heaping of an immense mass of refuse on top of the secondary grate several feet thick, cannot be recommended. The weight in itself causes the component parts of the refuse to sink into a very close-lying mass. Then, again, in wet weather, when the refuse contains a heavy percentage of moisture, this will inevitably find its level. From the point of view of storage it does not commend itself, as all sanitarians agree that if refuse is stored at all, it should not be stored near heat; and in Mr. Watson's own words, "it is stored on top of the fire."

Mr. Watson is in favour of the very finest workmanship and the best materials. This is very commendable, but even if it is carried out to the letter, accidents will happen. Mr. Watson apparently does not agree with putting destructor cells down in duplicate. In fact he says that "such expedients are quite needless." This is really an extraordinary view, because every destructor requires to be shut down for cleaning at intervals of not longer than three months; and after a plant has been running for three months continuously, it requires several days *to cool down before the men can even enter the flues for cleaning purposes*. Perhaps Mr. Watson can suggest what local authorities can do with their refuse at such times; and as he is a strong advocate of the destructor for power purposes, how could a town possibly be lighted or sewage or water pumped if a plant was not put down in duplicate, and the destructor was relied upon solely for providing this power? Even allowing that no accident happens, cleaning must be done; and this fact alone is sufficient to make it absolutely necessary to put down a destructor in duplicate, so that when one battery of cells is off for cleaning, another may be put in work immediately.

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Electrical Engineering in the Colonies.

Colonial development is a theme of surpassing interest at the present juncture. To carry it out to any reasonable extent must of necessity be an undertaking of mammoth proportions, a work which will be, we trow, one of the distinctive features of British industry during the twentieth century. Electrical

energy promises to be the most powerful agent that will be employed in bringing our possessions in other lands up to the level occupied by the more up-to-date towns and districts in the home country and in America. If we regard for a moment the great amount of money which is being laid out by municipal authorities throughout these islands for electric lighting and tram systems, we can gain some sort of a notion of what electrical development means; but we must also bear in mind that the most completely equipped city or town in England is only partly developed at present so far as electricity supply and street traction are concerned. A number of Australian and South African towns have already done something in these directions, but we are of opinion that far greater things would have been accomplished had British manufacturers and representatives paid more attention to the requirements of Colonial electrical work a few years ago. We have too often heard it complained that foreign manufacturers have too great a hold on the English electrical market, but for some years past it has looked as though we were losing ground even in British possessions, more particularly South Africa and Australia. In the broadest sense we are, of course, all anxious for Britisher and foreign rival alike to bring their influence to bear in the development of our lands across the sea; but for the sake of the prestige of the British manufacturer, and for the sake of the future welfare of British industries, it is, to say the least of it, undesirable that our foreign rivals should have things too much their own way. The fact that American electric stations and schemes generally are larger in size than most of the power works in England has sometimes had a marked impression upon British Colonials who have made it their business to go on tour to see

BUILDING A STONE "SADD" ON THE NILE.

what's what in England and America. This favourable impression may be expected to incline the Colonial to the belief that when he returns to his colony he will be able to obtain most electrical things better by going to the States for them. We are happy to believe that this impression of largeness will not be obtained much longer. With our dozen or more large electricity works in London and others in the provinces yearly adding to their plant; with the large electric power distribution schemes on the verge of execution; with the extensive electric tramway systems of Manchester, Glasgow, Liverpool and London now well on the way; with three underground electric railway systems in operation, two now tunnelling, and another dozen seeking Parliamentary approval, we shall in a year or two be able to show a large amount of important work which must leave a very powerful impression upon the Colonial visitor. But in the meantime, are we to allow our Colonial cities which are requiring electric lighting, power, and tram systems to continue to hold the view that Germans and Americans are in a better position to execute their contracts cheaply and expeditiously than are the British home manufacturers? It seems to us that the present is a fitting occasion for British manufacturers to subject themselves to a thorough heart-searching and see whether they come short in energy, enterprise, or "pushfulness" in their attitude towards Colonial electrical business, whether they are doing their best to cater for the needs of these foreign markets, and whether they are prepared to lay themselves out to do as well as, or better than, their rivals. It is complained, even now, after English electrical factories and workshops have been extended, and new ones set to work, that it is our works' output capacity that tells against us in competing for large electrical engineering machinery. The air is still filled with rumours of new works and works extensions on a large scale; such reports are especially welcome when we consider the undertakings likely to be arranged for during the next few years. The orders from English cities are very heavy at present, and will continue to be so for some years if all goes well; therefore it must be apparent how necessary it is to put forth special efforts if we are to be ready to supply the requirements of Colonial cities. In South Africa, for town lighting and tramway equipments, and also for mining power plants, there is a good deal of foreign-made machinery in use; Australasia has been very closely watched by American suppliers, who now have their attention specially turned in the direction of India. English representatives on the spot are essential, but they must be well backed by works at home.

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Electric Tramway Systems.

All electric tramway construction work now in progress throughout this country is being carried out on the overhead trolley system, but in several towns where lines have been equipped or are now equipping the more central thoroughfares are for the time being left untouched. The reason for this is that overhead wires and trolley standards are regarded as impossible obstructions for busy streets where horse and pedestrian traffic are heavy. Overhead wires have shown themselves to possess certain elements of danger for such thoroughfares, in spite of the precautions which have been taken. Of course, no one will dispute that there are important streets in the city of London along which, under present general conditions, no tramway of any kind whatever is permissible, let alone overhead wires and pole work. But the objections which are applicable to thoroughfares of this class do not hold good for suburban roadways on the

fringe of and leading to our great centres. There are very few who to-day oppose the trolley system for such conditions; it is accepted as the cheapest and longest tried of all the electrical methods. What, however, about the central crowded streets where tramways are required, but of the most unobtrusive kind? The Metropolitan Street Tramways Co. of New York changed a few years ago from horse and cable traction to the underground electric conduit. The cost of construction and equipment came to an enormous figure per mile compared with trolley lines, but the trolley was out of the question, and in the result the company found that the running cost per car mile worked out at a most satisfactory figure when placed beside its previous horse and cable costs. It would appear that the position in London, under the schemes of the London County Council, will be very similar. The Council's advising engineer, Professor A. B. W. Kennedy, has quite recently designed a special conduit for certain sections, and this has been passed by the Council itself, which afterwards submitted the drawings and general details to the Board of Trade and the local authorities whose districts are to be affected by it. The London County Council is not so concerned about dividend earning as others might be, so that it will not be materially affected by the extra capital outlay per mile. The running cost per car mile will necessarily be higher than for trolley if one adds the interest on capital outlay. £30,000 per mile of double track is to be about the cost of the conduit lines. This is an enormously higher sum to pay because of the difference of London streets; but it has been resolved upon, and the time is already so late for the metropolis to take its plunge in the direction of improved transport facilities that any change will be acceptable to the populace, though perhaps not so pleasing to some of the advocates of other electrical systems. We are not aware at this moment how many miles are to be laid on the conduit principle of Professor Kennedy; other central thoroughfares are to be supplied with surface-contact or stud electric tramways, though upon whose system is not yet decided. There are numerous methods to choose from, and all of these have, we believe, been investigated. Battery traction, judging by what has recently occurred in America, on the Continent, and in this country, does not appear to have much of a chance, however desirable it may seem. We believe that battery traction will shortly have a further trial in this country, and of course we wish it well. Battery inventors and manufacturers have for years past been doing their best to produce cells of lighter weight, greater durability, and higher capacity per lb. of plate, and they have done good work. They have strained hard to obtain something commercially practicable for automobile traction, and seem to have come pretty near to what has been hoped for, judging from the performances of some of the electrical vehicles which entered for the Automobile Club's recent trial runs. Another system of electric traction which it is proposed to introduce into the neighbourhood of London is that known as the "Schuckert" surface-contact system. The South-East Metropolitan Tramways Co. is at the moment negotiating for permission to equip lines at Greenwich on this principle. The "Schuckert" system, of which full illustrated description will shortly appear in these pages, has not been previously tried in this country, but for several years a section has been operating at Munich; there valuable data has been obtained, from which further improvements in the system have resulted.

Tramways v. Observatories.

We recently mentioned in these columns that the London United Tramways Co.'s new electric trolley lines in West London were approaching completion. They are ready for running at any moment when the Board of Trade will allow them to be started, but at the present moment there is a more or less heated controversy proceeding as to the effect of the return current upon the magnetic instruments at Kew Observatory. There appear to be two alternatives to set matters right—either the magnetic observatory must be shifted to some spot on earth where electric tramways are not likely to trouble it, or the Tramway Authority must, as required by the Board of Trade, lay down (at great cost) an insulated return and keep the leakage at its minimum. The matter really resolves itself into a question of "Tramways *versus* Observatories." Which are of the greater consequence to the inhabitants of London, and to the engineering industry?

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Tall Buildings.

The great Park Row Building of Chicago, illustrated in our frontispiece, shows what advancement is being made in that branch of civil engineering. Four hundred feet in height, and consisting of thirty stories, it is the most remarkable structure of its kind in the world. It is probable that the limit to height has been reached, not because of any constructive or engineering reasons, but mainly on account of the enormous cost of building and afterwards keeping in repair, making them, in the majority of instances, financial failures. Danger of fire also militates against further extension.

Some of the large American buildings are in themselves small-sized towns, having their own elaborate sewage, waterworks, electric lighting, heating and lift systems. The building we have illustrated has no less than a thousand suites of offices.

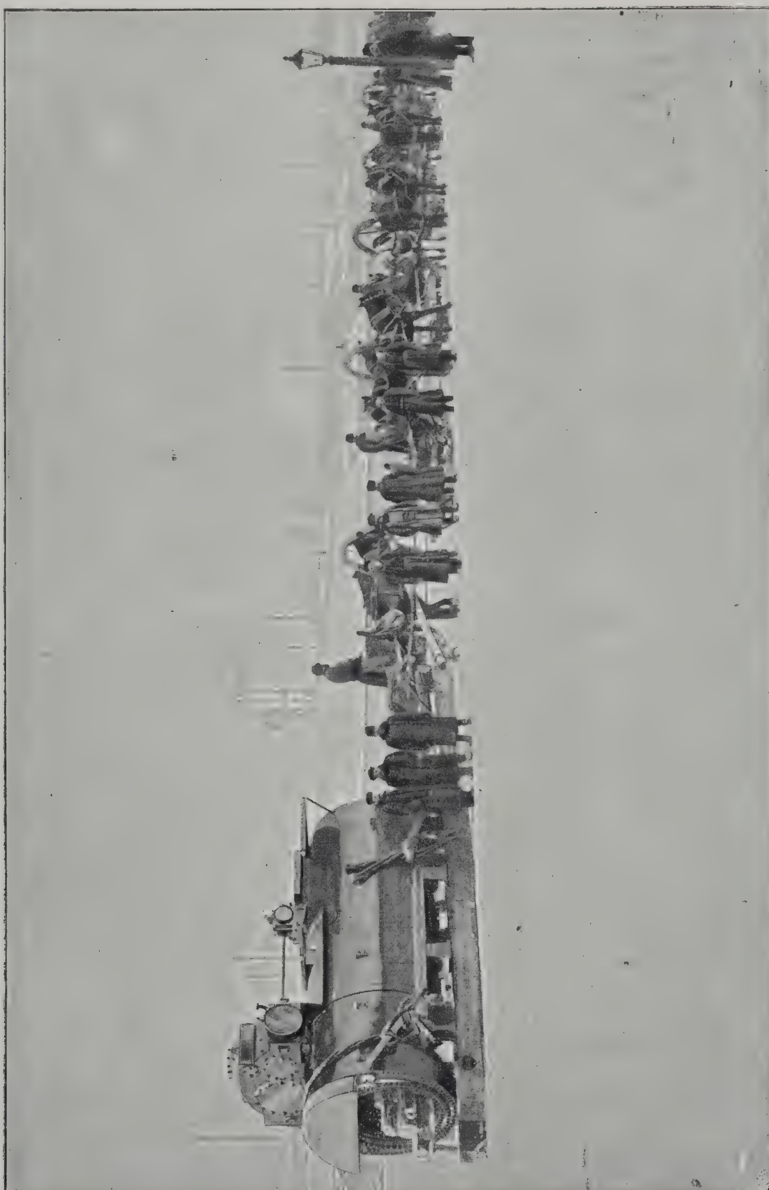
As to constructive difficulties as stated by Professor Robert S. Ball in the ENGINEERING TIMES* :—

"We have not yet, even in the highest buildings, approached the limit of compressive stress which divides absolute safety from uncertainty. The steel columns on which the great system rests are strained to a small fraction of their ultimate strength, and such care provides a wide margin for contingencies which arise during the life of any structure. The highest wind acting on the enormous broadside is provided for in the design, and eccentric loading, or the loading of one side of a column to the exclusion of the other, is met by increased section of metal to compensate for the severe strain to which engineers are aware that such members suffer under conditions of this kind.

"The cheapest brick would resist crushing under a uniform column of eight hundred feet high of the same material, and inferior granite would sustain a column of four thousand feet without giving way. When we come to steel, we find that a column of uniform diameter three miles high would resist crushing if made of the poorest product of the open hearth furnace when the effect of bending is neglected, so that, though the columns and walls of a building transmit the floor loads, in addition to their own weight, to the oundations, we need have no apprehension concerning the materials which the builder of to-day has at his disposal. Structural steel, never so cheap as at the present time, forms the basis of these large structures, and to the great skeleton of this material is attached the external coating of terracotta, brick, or stone, which hides the real and essential part of the structure,

* Vol. II. No. 1.

and gives it the appearance of being wholly the work of the mason or bricklayer."



TRANSPORTING A LARGE SEMI-PORTABLE "WOLF" ENGINE IN SIBERIA.

New President I. Mech. E.

The new President of the Institution of Mechanical Engineers elected in succession to Sir William White is Mr. E. H. Maw, co-editor with Mr. James Dredge of our esteemed contemporary *Engineering*. Mr. Maw is a well-known engineer, and deservedly popular. The author of several books, the best known of which perhaps is "Recent Practice in Marine Engineering," he has for many

years taken a keen interest in microscopy and astronomy. In connection with both subjects he has made useful research work. He is President of the British Astronomical Association.

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A New Technical Monthly.

"Within recent years, almost within the last decade, a new science has been brought into being, and on its foundation new industries have been built, industries which, if the vigour of their youth be in any way a measure of the strength of their maturity, bid fair to equal in extent and importance rivals which count their years from beyond the birth of civilisation. The science is the fascinating borderland between the domains of physics—and, in particular, electricity—and chemistry. The industries are those chemical manufactures in which electricity plays an all-important part: the electrolytic separation and purification of metals, the formation of soda-bleach and other alkaline products, the important and interesting materials yielded by the electric furnace, and other valuable substances too numerous to mention. There is one great industry indeed, which, but for the timely aid of electricity, would have remained undreamed of—much less realised; we refer, of course, to the extraction of aluminium from its ores. In addition to these quite recent applications of electro-chemistry, we have the older industries of electroplating and the manufacture of batteries and accumulators." To be the exponent of these industries is the *raison d'être* of the *Electro-Chemist and Metallurgist*, the first number of which lies before us. Hitherto they have not possessed an exclusive representative paper, and the issue of this new periodical therefore will fill a deep-felt want. A rough estimate of the character of the journal may be formed from the following titles of some of the articles which appear: "Some Recent Progress in Electro-Chemistry"; "On Some of the less well-known Carbides, Borides, and Silicides," by R. S. Hutton; "Electro-Chemistry at the 1900 Paris Exhibition"; "Deposition of Metals from Mixed Electrolytes," by Professor R. A. Lehfeldt; "The Present and Future of Accumulators," by E. J. Wade, etc. Space is also given to Reviews of books, Abstracts from contemporary foreign journals, New Patents, Correspondence, and Chemical and Metal Trades Reports. It will be seen, therefore, that this journal is representative in character, and so should receive the support of manufacturers and dealers and all connected with the electro-chemical and metallurgical industries. We wish our contemporary a long and prosperous career.

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No more Submarines for U.S. Navy.

In explanation of its decision against building more submarine torpedo boats at this time, the American Naval Board on Construction has filed a report with the Secretary of the Navy, in which it is pointed out that the failure of the General Board of the Navy and the Construction Board to include torpedo boats in their building programme for this year "may be accepted as conclusive evidence that they did not consider it advisable at this time to increase the number above those now authorized." The Board shows that it regards submarine boats as experimental, and asserts that the tests of the *Holland* at Newport last year, "were interesting, and answered the purpose for which they were intended, namely, to instruct the crew, but nothing more." As to these experiments with the *Holland*, the Board says:

"During the manœuvres of the North Atlantic fleet off Newport last summer, the *Holland* participated, making a sur-

face run of seven miles outside Newport harbour, in charge of her naval crew only, and succeeded in getting within striking distance of the battleship *Kearsage* without being discovered, due, no doubt, to her small size. She was ruled out, however, as the *Kearsage* had already been put out of action by another ordinary torpedo boat, which also got within striking distance unperceived, and it has been stated that on account of the latter the vigilance of the lookouts on the *Kearsage* had been relaxed when the *Holland* made the attack. Be that as it may, the conditions by no means simulate the actual warfare, and the *Holland* was not on that occasion used as a submarine boat, nor did she accomplish more than an ordinary torpedo boat."

The opinion is expressed by the Board that the price of $170,000 each for the submarine boats authorized is very high, unless the expenses of the Holland Company in developing the boat are taken into consideration, in which case the price is not excessive. "Without desiring to discredit the *Holland* in any way, or to detract from her merits," the report says, "the Board is of the opinion that the utility of the boats of this class has not been sufficiently demonstrated to warrant the construction of others than those already authorized — eight in number — which are considered a sufficient number to experiment with."

In conclusion the Board had this to say: "Should Congress see fit to authorize any more submarine boats, the Board is of the opinion that no special type should be specified, but that the Secretary of the Navy should have discretion to contract for such boats as in his judgment are likely to prove the most efficient and the best suited for naval purposes, thus opening up competition and giving other inventors a chance."

Record Bridge Building.

The Widnes Foundry Company are said to have established a world's record in bridge construction. On Nov. 10th the Crown agents for the colonies ordered a steel bridge, 520 ft. long, for the Lagos and Kumasi Railway, to be erected at Abeokuta, across a tributary of the Niger. The bridge is in six spans. It had to be ready in nine weeks, three weeks less than was allowed for the much less difficult Tugela Bridge. The Widnes Company have beaten the makers of the Tugela Bridge by three weeks.

Continental Electrical Machinery.

Our Sheffield Representative sends us a copy of the Report by Mr. Edgar Fedden to the Electric Light Committee of the Sheffield Corporation on Continental practice in single-phase and polyphase alternating systems. This report contains some very interesting impressions of the state of electrical enterprise—especially central station work—in France and Germany. The following are his concluding observations:—

The employment of high-pressure alternating currents, preferably of the poly-phase type, have given a tremendous impetus to the growth of electrical undertakings for the transmission of power over large areas throughout the Continent.

Alternating currents are successfully generated and transmitted at high voltages without the use of step-up transformers, as has been usual in American practice.

Alternating currents are now employed for work which a short time ago was considered to be totally impossible.

Poly-phase machinery is long-lived on account of the simple and solid construction of the type of generators and motors.

Owing to the great development of high tension alternating current the switching and controlling gear has been

completely remodelled and greatly improved within the last few years, in order to meet the severe demands made upon it, without risk of breakdown or danger to attendants.

Poly-phase motors will in particular be used in preference to continuous current in mines and foundries, and other places of similar description, on account of the rough treatment and heavy duty which they can withstand, and also because no skilled attendance is required.

Poly-phase motors are now being used on the Continent for driving jib-cranes, travelling cranes, traverses, rolling mills, turn-tables, plunger pumps, rotary pumps, centrifugal machines, lifts and elevators. They are also adapted to all kinds of ventilators, ring spinning frames, weaving looms, and in fact almost every type of machinery.

I made numerous inquiries at the different factories I visited with regard to the use of two and three-phase current, and was informed that they were practically the same as regards efficiency, duty and starting torque.

The only apparent benefit of three-phase over two-phase is in the saving of copper in the mains for long distance transmission.

There are a large number of installations on the Continent which are most successfully run by two-phase alternators.

The largest two-phase induction motor which I believe has ever been made is that manufactured by the Brown, Boveri Company. It is 1,000 h.-p., taking 5,000 volts direct, and is connected to a centrifugal pump running at 455 revolutions per minute. This set is used at the Geneva waterworks for pumping water to a height of 460 ft.

Not the least remarkable feature of this combination is that a centrifugal pump should be employed for throwing water to so great a height.

Poly-phase traction is now being used on the Continent for a number of mountain railroads, and I quite expect that within a few years it will become general for light railway work.

The electricity supply works of the later construction are designed and built sufficiently capacious for the reception of machinery that may be required for some years to come, although this places a rather heavy burden on the starting of a new undertaking. They are generally well-designed, spacious, lofty, and well ventilated. The walls are all faced with enamelled brick, and the floors are handsomely tiled.

In most cases no pipes of any sort are above-ground, ample space being provided underneath the floors for the reception of all steam, exhaust, water, and compressed air pipes, and all the necessary cables. The condensers are also placed underground.

There is also every convenience for the comfort and welfare of the people connected with the undertakings. The chief engineer, his assistant, and the leading hands are usually provided with good house accommodation on the premises, and in most cases superannuation funds are in existence to provide for the members of the staffs after a number of years of service.

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That Message from Mars.

It has been stated by an authority, whose weight will be determined by the mental attitude of his readers, that the day is near at hand when we shall be able to communicate with the other planets and preferably with Mars. It seems that in searching for a suitable location for a laboratory in which to conduct experiments in the wireless transmission of energy, Nicola Tesla found the desired conditions at a point some ten miles from Pike's Peak, at an altitude of several thousand feet above the sea. During the eight or nine months wherein Mr. Tesla was busy

in the rarefied atmosphere of his laboratory, he seems to have produced some very spectacular effects; for, whereas in his New York laboratory, he was able to produce electrical discharges only 16 ft. in length, and of 8,000,000 volts pressure, he here gradually "learned how to confine electrical currents of a pressure of 50,000,000 volts; how to produce electrical movements up to 110,000 h.-p.," and that he finally succeeded in "obtaining electrical discharges measuring from end to end 100 ft. and more." Yet, in spite of his familiarity with 50,000,000 volt currents, Mr. Tesla did not disdain to study "certain feeble electrical disturbances, which, by their character, unmistakeably showed that they were neither of solar origin nor produced by any causes known to" him "on the globe." After deep thought upon the subject, he has finally "arrived at the conviction, amounting almost to knowledge, that they must be of planetary origin."

It would be interesting, and possibly vastly entertaining, to be supplied with the process of ratiocination by which Mr. Tesla deduces from the existence of certain puzzling electrical disturbances his "conviction, amounting almost to knowledge," that these disturbances had been launched at our particular planet from some other planet (preferably Mars), that was desirous of intercourse. Signor Marconi has suggested that these disturbances (which seem to have worked with such brilliant results upon Mr. Tesla's imagination) were due to atmospheric electricity which is especially active at such a high altitude as that of Mr. Tesla's laboratory; and Sir Norman Lockyer pertinently asks why, if electrical energy had been transmitted from Mars, it should have made its presence manifest in Colorado only; since all magnetic observatories in the world would have been simultaneously aware of it?

That some of the planets may be inhabited is possible, and there is nothing in our present knowledge of electricity absolutely to forbid the hope that in some future day we may learn how to fling forth intelligible electrical impulses into inter-planetary or even inter-stellar space; but, as the *Scientific American* says, it will certainly need something more than mere observations of some unexplained electrical impulses on a Colorado mountain to prove to a demonstration either the one proposition or the other.

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Economy Guarantees of High Speed Simple Engines.

In a paper on the above subject read by Mr. E. J. Armstrong at a recent New York meeting of the Engine Builders' Association, he said it was his belief that the single-valve automatic is not always given a fair chance. The matter of economy does not always receive consideration. The engine that runs smoothly, noiselessly and punctually will have friends and purchasers whether it uses much or little steam. Mr. Armstrong had no desire to advocate improvement in economy to the detriment or neglect of other qualities which go to make up successful machines, but he believed that many engine builders had but a very imperfect idea of what their own engines were capable of. If the subject were more amenable to mathematical treatment, the case would be different; but in spite of the marvellous advancement in science at the end of the century, he believed that the exact formula for the economical performance of the steam engine has yet to be written. In view of the fact that the steam used by an engine often costs each year as much as the engine itself, it would seem as if the customer might consider steam economy as of first importance and price as a bad second. Yet even a small difference in price or a personal preference

will decide a purchase without raising the question of economy at all. A difference of 10 per cent. in steam consumption between two engines might easily place the more wasteful one in the position of being too expensive, even as a gift; but there is no doubt that there have been, and still are, even greater differences than this between engines that are sold on equal terms. It is singular that customers who figure so closely on other matters should be so careless and unbusinesslike in this, or that builders should expect to market engines with no economical record and not even a pedigree. Mr. Armstrong believed that this rather anomalous condition of things would soon be brought to an end; that for years there had been an increasing tendency among customers to raise the question of steam consumption, and that builders of engines must recognise and prepare to meet a demand for definite promise and performance in the matter of economy. This should be welcomed, not as a hardship, but rather as an opportunity. It is essential to obtain more exact data concerning the performance of automatic engines, and in making efforts to improve the quality of work turned out, the first step is a systematic effort to find the defects in that work. The first move in reducing cost is to find out what things are costing, and the way to improve the economy of engines is to test them systematically and to learn their deficiencies. It is not usually practical to test engines of small size after installation; the expense is disproportionate and the difficulties in the way of obtaining accurate results are great. The liability to error and the impossibility of running preliminary tests make it unsafe to make close guarantees to be demonstrated in this way. The proper place to test an engine is on the shop-testing floor. With properly arranged apparatus tests can be made there in a short time and at little cost. In estimating the steam consumption of an engine of a size or under conditions which have not yet been tested, there were two ways of figuring; one was to determine the losses in the engines separately from the steam accounted for by the card. This method, while quite complicated, is the more accurate of the two and is sometimes very valuable in working out a close guaranty. The other plan is simply to learn the general effect of the different conditions which affect economy and to use some previous tests as a basis. Mr. Armstrong added that the building up of a better reputation for automatic engines was well worth the attention of ts manufacturers. No guarantee of economy should be given unless its fulfilment by actual trial is provided for. Where there is no certainty that a test will be made, there is the temptation to give a lower water rate than would be the case were its fulfilment one of the conditions, especially if accompanied by penalties for failure to meet the terms of contract. This question of penalties, although considered quite onerous by engine builders, if not provided in the contract, the only penalty is the non-acceptance of the engine; and as this is often impracticable because of lack of time, there is a good chance that the guarantee is not worth anything. Definite penalties at least have the effect of protecting those who really make their guarantees in good faith and with a knowledge of what they can do. There is nothing wrong about it from the purchaser's standpoint. A deficiency in economical performance means a direct and continuous loss to him. . . . There is one feature of the situation that is manifestly unfair and calls for remedia action. Better economy costs money. It may not actually cost more to build the high duty engine than a wasteful one, but it costs a good deal more to learn how, and to keep up the

standard afterward. It costs money to tune an engine up to meet a close guarantee, and testing engines is an expensive business at the best. There should certainly be an addition to the price when guarantees are required. Mr. Armstrong suggested that all duty guarantees should provide or their fulfilment on the shop-floo test before shipment and should always be considered as an extra, it being optional in all cases with the purchaser to accept the proposal with or without the guarantee. If the guarantee does not mean anything, it should not be made. If it does stand for something, it costs a good deal and is worth to the customer all that he is likely to be asked for it.

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Shipbuilding in 1900.

From the yards of the United Kingdom there were launched last year, exclusive of warships, 1,442,471 tons gross of shipping; the rest of the world turned out 861,692 tons. If warships be included, the figures are: For the United world Kingdom, 1,510,835 tons; for the outside, 1,053,792 tons. Speaking roughly, then, we have a clear lead of the rest of the world combined by some 50 per cent. Our chief competitors are the United States, with an output last year of 358,557 tons; Germany with 260,751 tons; France with 165,348 tons. No other country reaches 100,000 tons, the nearest being Italy, whose Government bounties have brought the year's construction up to 67,522 tons.

* * *

A New Steam Meter.

A meter for measuring the amount of steam which flows through a steam pipe has been introduced in Berlin by A. Friedeberg. It is described as follows: Inside a horizontal length of the main, a flap-plate, hung from a horizontal axis, actuates, through an internal sector and rack, a conical plug valve controlling an opening in the top of the main. When no steam is being used, the plate hangs vertically and keeps the valve closed; when steam is flowing through the main, it turns the plate more or less toward a horizontal position, thereby opening the valve correspondingly, and the steam escaping through the valve is condensed in a worm. The water from the worm is either collected in a measuring tank, provided with a gauge-glass, or is delivered upon a bucket wheel, the revolutions of which are indicated upon a counter arranged to show the corresponding quantity of steam flowing along the main.

* * *

Engineering Training.

Mr. W. H. Allen writes in *The Appointments Gazette* on engineering training: It is somewhat difficult for young men desiring to become engineers to foreshadow their curriculum owing to the fact that no method has hitherto been thought of to direct the mind for the purpose.

Many parents have an idea that if their sons are unable to take up the positions of soldiers or clergymen they will make engineers, little thinking, perhaps, that the profession requires the very highest brain power the country can produce.

It is of very little use for any young man to enter the vocation unless he has a natural and keen inclination for it, as engineering, like all other pursuits, should have love of the occupation entwined with it in such a fashion that the toil becomes a pleasure in life. An engineer, to be a thoroughly qualified one, must have the theoretical principles instilled into him in early youth. The engineer of the practical form only, will find a great difficulty in keeping pace with the many brilliant young men who, having college education, are constantly finding practical posts in the different works in the country.

Probably the best plan to come to any determination would be to consider whether a lad is fond of books, not only those which give general descriptions of the achievement of engineers, but also of the books brought before him for general educational purposes. If so, it becomes quite a question whether it would be desirable for him to take his degree before entering the works or *vice versâ*. Certainly he should have some college training to be an engineer, but it would depend very much upon the bent of the man himself as to whether he should acquire this before entering the works or afterwards. If his mind is that of a student, let him graduate in college first, but if he is anxious to begin with manual work it would be desirable that he should be placed in the works direct from school. My experience with men who have left college shows that they immediately settle down to business; the natural desire for fun, so apparent in all schoolboys, has disappeared, and they begin at once to realize the value of time. The earnestness with which most college men have gone into the workshops is very apparent. On the other hand, several young men who have been here have found it an advantage to train the hands and mind after the manner of workshop routine in the first instance, and have then been able to understand more readily some of the deeper work of the University. The proper course to pursue would, however, depend very largely upon the natural talent of the particular student considered.

The training for young engineering students should certainly have in view a thorough knowledge of mathematics, so that all forms of mechanism which have to be designed and worked out can be done in the first instance mathematically. Many engineers differ on this point, but the writer prefers young students to consider their judgment in conjunction with the formula, it being remembered that every formula which is now used has been reduced to reliable form, the result of constant experiment and investigation, and is in no way hypothetical. It is clear that any-one trained under these conditions of combined theory and practice should be able to take an early place of usefulness in the works of engineers.

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U.S. Patent Office Business.

The report of the Commissioner of Patents on the business of the patent office for the fiscal year ended June 30, 1900, shows that there were received within that year 39,815 applications for mechanical patents, 2,263 applications for designs, 90 applications for reissues, 1,739 caveats, 2,103 applications for trade-marks, 872 applications for labels and 127 applications for prints. There were 26,540 patents granted, including reissues and designs; 1,660 trade-marks, 682 labels and 93 prints were registered. The number of patents that expired was 19,988. The number of allowed applications which were by operation of law forfeited for nonpayment of the final fees was 4,052. The total receipts of the office were $1,358,288.35; the total expenditures were $1,247,827.58, and the surplus of receipts over expenditures, being the amount turned into the treasury, was $110,400.77.

THE FEED WATER OF STEAM BOILERS CHEMICALLY CONSIDERED.

By H. C. STANDAGE.

THE question of the suitability or otherwise of the water used in the production of steam is one of the most important to all steam users, whether it be raised in large or small quantities. This is so because water that is used for such purpose is never chemically pure or free from solid matter. The solid matter present in water is the *bête noir* of all steam raisers, for this reason, that it is almost impossible to effectually remove the whole of the solid impurities commensurate with the commercial cost of effecting same. The solids in water are not only injurious to the metal, but by being deposited in a solid incrustation on the metal, increase the cost of fuel to a very great extent, and at the same time increase the wear and tear of the boiler plates, thus effecting a double injury; a film of incrustation $\frac{1}{6}$th of an inch thick will necessitate the use of 16 per cent. more fuel than would be required if the boiler plates were clean. A film $\frac{1}{4}$ in. thick increases the consumption of fuel 50 per cent., while a coating of scale $\frac{1}{2}$ in. thick increases the amount of fuel required 150 per cent. to produce the same amount of steam. Apart from this increased (and waste) consumption of fuel, the plates are materially damaged by the overheating to which they are thus subjected, and they are also subject to mechanical damage in the endeavour to remove the incrustation. As the layer of incrustation prevents the water reaching the metal, the plates become hotter than they would otherwise do. For example, the temperature of water boiling under atmospheric pressure in a clean vessel would not be more than 10° C. above the boiling point of water, but with an incrustation of only $\frac{1}{16}$th of an inch, the temperature of the water is more than 100° C. higher than the boiling point. This increased temperature materially affects the mechanical properties of the metal composing the boiler plates, and, *ipso facto*, the life of this is shortened. These few preliminary facts show the importance attaching to the quality of the feed water, and the necessity for a knowledge of same on the part of the boiler attendant. To help the latter individual to a knowledge of the chemical facts involved in the case, the present paper is written.

WATER.—In chemical composition water consists of two equivalents of hydrogen to one equivalent of oxygen, its chemical symbol being H_2O (to avoid confusion the older form of chemical notation will be adhered to in this article). With the exception of distilled water, no water is ever found of such absolute chemical purity as to consist of these two chemicals only; many other substances are found in water, not chemically *combined* but simply mechanically *mixed* with the fluid. This distinction must be borne in mind, as all operations for the purification of water are devised with a

view to eliminate the solid matter which is held in suspension, and although many of these may depend on chemical reactions occurring between the solid matter and the substances added to the water to effect the removal of the solids, the water itself remains unchanged in its chemical composition. For example, a water in which sulphate of calcium ($CaSO_4$) is simply a mixture of (fluid) H_2O and (solid) $CaSO_4$ held in suspension, and even though this calcic sulphate may be chemically changed into solid* sulphate (Na_2SO_4) by the addition of carbonate of soda (Na_2CO_3) to the water, the fluid will still consist of water plus the salts of sodium and calcium, *e.g.*,

$$H_2O + CaSO_4 + Na_2CO_3 = $$
$$H_2O + Na_2SO_4 + CaCO_3.$$

By the above equations it is shown that water containing solid calcic sulphate, when carbonate of soda (which is soluble in the water) is added, still remains water plus the addition of sulphate of soda (Na_2SO_4, which is a salt also soluble in water) and calcic carbonate (which is a solid body insoluble in water). In other words, although the calcic and sodic salts have been changed in composition, such changes have not affected the *chemical* composition of the water in which such changes occurred, but that the fluid still consists of H_2O. It is well to bear this fact in mind, so as to thoroughly appreciate the reactive changes that are chemically brought about (and expressed below) during the additions of mineral matter made to the water to effect the elements of the solid impurities in it which are injurious to the boiler, or hinder steam raising. Roughly speaking, there are three classes of water.

* The sodii sulphate will be a solid only when the water becomes concentrated sufficiently to allow the sulphate to crystallize.

Calcareous Waters.—That is, water containing salts of calcium; these waters are usually "hard" waters.

Peaty Waters.—These are usually soft, but contain a lot of vegetable matter, which is rich in free oxygen.

Saline Waters.—These waters are usually alkaline, and contain soluble salts of metals and non-metals.

There are several other classifications, such as spring water, rain water, river water, sea water, etc., but any one of these can be placed in one or other of the above classes of water, their special names indicating their source of origin.

Spring water may be "hard" or "soft," according to the source of origin or geological stratas it has passed through in its course to the "spring" from which it issues. Thus, if it has passed through any cretaceous or limestone strata it will be of a calcareous nature. Spring water that has passed through sandstone and other strata that is free from lime, magnesia, and other alkaline earths will usually be found to be "soft," but ferruginous salts may be present.

Water that has drained from bogs, meadows, or morasses will be of a peaty nature, and contain vegetable refuse and salts of a vegetable nature (oxalic acid, etc.), as well as various mineral salts.

Rain water is usually considered to be free from solid matter, but it is never pure. As a matter of fact, it has carried down in its course through the air all the impurities therein (gases, soot, vapours, etc.). In addition to this, rain, in pouring over roofs, gutters, etc., of buildings, will carry a lot of dirt and refuse.

Saline water will be such as contains soluble salts, as sea-water, water of estuaries, and mouths of rivers. It will thus be seen that it is next to impossible to obtain a pure source of water that is free from impurities, which are all more or less injurious when such waters are used as feed waters of steam boilers.

(the use of filtered or "potable" water, such as is used for domestic purposes, is excluded from consideration on account of its cost (*i.e.*, to filter). It will thus be seen that it is a *sine quâ non* to have the water of the district which supplies the feed water analysed by a skilled chemist, so as to know its actual impurities, and therefore make suitable allowance for same when feeding the boiler, or treating it to prevent incrustation.

The following table will give the usual mineral impurities found in calcareous ("hard") and peaty ("soft") waters.

MINERAL IMPURITIES IN CALCAREOUS WATERS.

	Grains per gallon.			
Calcic Carbonate, $CaCO_3$	15·23	12·86	23·72	19·55
Calcic Sulphate, $CaSO_4$	12·04	–	7·31	16·08
Magnesia Chloride, $MgCl_2$	—	—	6·29	28·71
Sodii Sulphate, Na_2SO_4	6·97	12·67	—	—
Sodii Chloride, NaCl	4·70	25·39	29·82	20·25

MINERAL IMPURITIES IN SOFT (PEATY) WATERS.

	Grains per gallon.	
	Water of the Wye.	Moorland Water.
Sodii chloride, NaCl ...	1·04	1·07
Calcic chloride, $CaCl_2$ ...	0·06	—
Calcic nitrate, $Ca(NO_3)_2$	0·02	0·41
Calcic sulphate, $CaSO_4$	1·12	—
Calcic carbonate, $CaCO_3$	2·88	0·77
Magnesia carbonate, $MgCO_3$	0·95	—
Silica SiO_2 ...., Sesquioxide of iron, Fe_2O_3, Alumina, Al_2O_3	0·26	—
Organic matter	0·27	—
Sodii sulphate, Na_2SO_4	—	0·71

A closer consideration of these several classes of water will give us a more intimate knowledge of the usefulness and otherwise for feed water purposes. "Hard" waters are waters that have been in contact in any way with calcic carbonate, and will contain a small portion of this carbonate, but if the water be free from carbonic dioxide (CO_2, commonly called "carbonic acid"), the presence of the carbonates will be indicated by a cloudiness or milky colour being given to the water, such colour being due to the carbonate being merely mechanically suspended in the fluid, but small quantities of calcic carbonate may also be present in the water without giving any such evidence of its presence. Where, however, the water has been obtained from districts rich in lime, chalk, or other calcareous salts, then the water will contain a quantity of carbonic dioxide. Now it is a fact to be noted that when water contains carbonic dioxide, such water will hold in solution (*not mechanically suspended*) carbonate of calcium, magnesium, etc.

It is supposed by some authorities that the carbonic dioxide unites with the calcic carbonate, and forms therewith calcic bicarbonate of the composition $CaH_2(CO_3)_2$, but as there is always a surplus quantity of CO_2 present in the water (more, in fact, than suffices to combine with the carbonate to form it into bicarbonate), the CO_2 that is in combination with the carbonate is termed "half-bound," and the surplus CO_2 is called "free."

Now another fact to be noted is that when water containing carbonates in solution is boiled, the carbonic dioxide is expelled by the heat, and the carbonate is thus present in the water in its solid form, and, as a consequence, settles or falls to the bottom of the fluid. Such deposit of calcareous carbonate in a feed water is usually in a powdery or pulverulent state. When, however, calcic sulphate is present in conjunction with calcic carbonate, then the deposit formed by the precipitated salts (calcic carbonate and sulphate) is a very dense, hard, and coherent one, so dense, in fact, that it is very difficult for

the heat of the furnace to pass through (*vide supra*). The precipitation of the calcic sulphate is not affected by the temperature of boiling water 212° F. under atmospheric pressure, but when the temperature of the water in the boiler is higher, then the calcic sulphate is precipitated in the anhydrous form (as $CaSO_4$)—that is, without the water of crystallization.

In the following tabular analysis of hard boiler incrustation from hard calcareous waters, the pressure being 50 lb., it will be seen that the calcic sulphate is freely precipitated.

	I per cent.	II per cent.	III per cent.
Calcic carbonate, $CaCO_3$	55·65	—	81·10
Calcic sulphate, $CaSO_4$	31·96	97·01	9·86
Magnesia hydroxide, $Mg(OH)_2$	7·11	0·37	2·58
Water....................	—	1·75	—
Sesquioxide of iron, Fe_2O_3 .... Alumina, Al_2O_3	2·10	—	1·48
Silica and insoluble matter..................	2·46	—	3·54

Carbonates of magnesia are similar to carbonate of calcium in rendering water "hard." In the case of these salts of calcium and magnesia which can be precipitated by boiling the water the "hardness" is only temporary, but when other salts of these metals, such as calcic and magnesia sulphates, chlorides and nitrates are present, then the hardness of the water is permanent, because such salts are not thrown out of solution by boiling the water.

As the carbonates are not precipitated by boiling the water under atmospheric pressure, but only under the pressure obtainable in a boiler, it is not possible to determine, except by actual experience, whether the "hardness" of water is temporary or permanent. Neither is it easy to determine, except by actual experience with the water, what will be the amount of incrustation or scale deposited. Even a preliminary analysis of the water will not disclose these facts. Nothing but actual experience with the water under working conditions will give accurate results. There is one good resulting from the use of a hard, calcareous water that produces much scale, viz., that such water will not cause corrosion of the boiler plates, but will, in fact, prevent them from corrosion. As a matter of fact, a very thin film of such incrustation is a positive protection to the plates, but for economy of fuel the film should not be too thick.

The following explanation concerning the nature of hard water will show in what way these calcic salts act:—

The Saponification of Hard Water.—The term "soap" is applied to the compound which is formed by the action of alkalies and oxides on the fatty acids of oil and fats, the combination of the two bodies (*i.e.*, alkali and fatty acids, or oxide and fatty acids) producing the compound which we term soap. Thus, in the case of common hard (soda) soap when sodii hydroxide ($NaOH$) is added to an acid oil or fat, the sodium combines with the fatty acids (oleic, stearic, palmatic, to form oleate, stearate, and palmitates), they comprising all what we call "soap," while the hydroxyl (OH) in the sodii hydroxide combines with the basic radicle glyceryl (C_3H_5) of the oil or fat to form

$$\text{Glycerine}\ \left(C_3H_5 \begin{cases} OH \\ OH \\ OH \end{cases} \right)$$

The following equation exemplifies the reaction of the soda-lye on the olein of linseed oil—

$$\underset{\text{Olein}}{C_3H_5 \begin{cases} C_{18}H_{33}O_2 \\ C_{18}H_{33}O_2 \\ C_{18}H_{33}O_2 \end{cases}} + \underset{\text{Sodii hydroxide}}{3NaOH} =$$

$$\underset{\text{Glycerine.}}{C_3H_5 \begin{cases} OH \\ OH \\ OH \end{cases}} + \underset{\text{Sodii oleate soap.}}{3NaC_{18}H_{33}O_2}$$

Now it should be remembered that the soaps formed by the alkalies sodium and potassium form soaps which are miscible (soluble) in water. It should also be noted that oxide of many metals acts towards the fatty acids of oils and fats precisely like caustic alkalies; that is, such oxides combine with the fatty acids to form oleates, stearates, etc., of the metal (in other words, such oxides are said to be "saponified," *i.e.*, a metallic soap is the product of such union). These metallic soaps are more or less soluble in water, but some of them are positively insoluble, such, for instance, as the metallic soap formed by calcic salts. (It is easy to prove this by mixing a little lime with water, allow the water to stand until clear, and then, after putting a spot of oil in the palm of the hand, dip the other hand in the lime water, and then rub the two palms together, when the oil will become of a curdy mass that is repellant to the water, and makes the hands seem hard and harsh to rub together. The oil, in fact, has become converted into a small piece of lime soap, which is insoluble in the water, and has no detergent properties whatever; that is, such a curdy mass will not mix with any fat or oil so as to emulsify same in water (common laundry soap will unite with oil, fat, etc., and allow same to be dissolved in water). It is due to this non-soluble nature of lime soaps that waters containing calcic salts are termed "hard." They will not lather while the calcic salt is present. A lather is the product of the union of the detergent soap with the fatty body or grease it is intended to remove or cleanse by washing same with the soap. The lather, in fact, is the emulsified form of suet fat or grease. The lather produced by a soap is a good characteristic test of its quality. Now the presence of this curdy, non-miscible compound in a water is extremely injurious to the "life" of a boiler (which we shall see when treating of the various corrosive and destructive agents that act in the interior of a boiler). The following equation expresses the chemical reactions that occur when water containing calcic carbonate is brought into contact with the fatty acid contained in common sodium soap:—

$$\begin{array}{rcl} CaSO_4 & + & 2NaC_{18}H_{35}O_2 = \\ \text{Calcic Sulphate} & + & \text{Sodii stearate *} \\ Na_2CO_3 & + & Ca(C_{18}H_{35}O_2)_2 \\ \text{Sodii carbonate} & + & \text{Calcic stearate} \\ & & (\textit{i.e.}, \text{ lime soap}) \end{array}$$

The above equation also expresses the fact that 100 parts of calcic carbonate will react with 612 parts of common soap to form 606 parts of an insoluble lime soap (the curdy mass which is found on mixing soap with limey water).

Now suppose the feed water contains 20 grains of lime per gallon of water, then each gallon of water will cause the formation of 122 grains of lime soap. This number of grains multiplied by the number of gallons of feed water, passed through the boiler in a given time, will give the number of pounds of lime soap formed therein from the use of hard water. The above equation refers to calcic carbonate, but for all practical purposes calcic sulphate may be considered to have the same action as the carbonate. Consequently, when both carbonate and sulphate of calcium are present in the water, a still further increase of lime soap is produced. As the soap produced by magnesia salts is also a hard, insoluble one, we then see what a very large amount of injurious matter there is in a feed water which contains the carbonate and sulphate of these metals. Let us now turn our attention to the quality of "soft" water.

Rain water that is collected from

* The chief fatty acid in fat and grease is *stearic*; consequently the soap produced is a *stearate*. $NaCl_{18}H_{33}O_2$ is *oleate* of sodium; $NaC_{18}H_{35}O_2$ is *stearate* of sodium. Oleates are usually semi-solid stearates solid masses.

roofs free from metal is very free from mineral matter, and is considered the purest of all "soft" waters. Akin to rain water is water which has percolated through silicious strata, and much soft water that passes over meadows, bogs, marshes, along streams, and takes up a quantity of peaty matter from the vegetation over which it flows; the facility with which such peaty matter is taken up being facilitated by the absence of calcareous matter in the water. The peaty ma ter thus taken up consists chiefly of vegetable acids, and such acids, when in contact with calcic salts, form insoluble salts, which are not dissolved by hard water. For example, the vegetable acid, oxalic, forms the insoluble oxalate of calcium. If these vegetable acids be not neutralized by combination with other bodies, they impart a feebly acid quality to the water, and thereby render it liable to set up corrosion of the boiler plates.

In peaty water, as in all natural water, there is always a quantity of dissolved or free oxygen; consequently, as such waters run over earths rich in metallic salts, this oxygen combines more or less with the metals to form an oxide. For example, a water that contains free oxygen, when passing through sand that is deeply stained with oxide of iron, will become highly charged with salt of iron (become ferruginous); so likewise will other earths that contain ores or salts of metals. Now the oxides that are thus formed are basic in character, and by combining with the peaty acids, set up a chemical reaction on the metal of the plate, and corrode same. The actual nature of the various metallic salts that are present in such peaty water can be determined only by analysis, and in many cases there are substances present which will act on lead and other metals, as well as on the iron boiler plates. The analyses given above indicate the nature of the metallic salts found in soft waters.

The third-class, *saline waters*, is typified by sea-water. This, however, is a very extreme case, but other saline waters are depending on local circumstances, as, for example, the geological nature of the district in which they abound or have passed through, the nature of the mines near which the water is located, etc. The exact nature of the saline matter present must be obtained by analysis. The following is an analysis of the water of the Irish Sea, and represents an average composition of sea-water. In particular districts, however, as, for example, estuaries, and proximity of rivers, bogs, and the geological nature of the land forming the coast, the concentration of the water varies, but the proportion of the salts to each other is pretty constant.

Constituents of the Irish Sea (in parts per thousand*).

	Parts per Thousand.
Sodii chloride, $NaCl$	26·44
Potassa chloride, KCl	0·75
Magnesia chloride, $MgCl_2$	3·15
Magnesia Bromide, $NgBr_2$......	0·07
Magnesia sulphate, $MgSO_4$ ...	2·07
Calcic Sulphate, $CaSO_4$	1·33
Calcic carbonate, $CaCO_3$	0·05
Iodine	Trace

As the sea-water is fed into a boiler, a point of concentration is reached at which the soluble salts begin to separate, and to ascertain this point it is necessary to test the water in the boiler from time to time by means of a salinometer (a special form of hydrometer), which indicates the specific gravity of the water tested. When the point of greatest concentration is reached, the water must be thrown out. In boilers where a large quantity of steam is raised, it is more economical to use condensing apparatus, instead of feeding the

* Sea-water is so greatly concentrated when compared with ordinary saline waters, that it is best to express the constituents thus than in grains per gallon.

sea-water direct into the boiler. (We shall, in a separate paper, discuss the means adopted of softening and pumping boiler waters.) In the case of brackish waters that are obtained from the muds of rivers, they contain vegetable matter, in addition to the constituents found in sea-water, and are proportionately more injurious. On looking over the list of substances found in sea-water (as per analysis given above), it will be noted that, with the exception of calcic sulphate and calcic carbonate, all the other bodies are soluble in water. As a consequence of this insoluble salt, sea-water will invariably give an incrustation when used in boilers, and such incrustation will take place even when the water is concentrated to a degree insufficient to permit the decomposition of the ordinary soluble salts.

The following analysis of the incrustation given by sea-water will show the large percentage of calcic sulphate deposited :—

	Per cent.
Calcic carbonate, $CaCO_3$	0·97
Calcic sulphate, $CaSO_4$	85·53
Magnesia hydroxide, $Mg(OH)_2$	3·39
Sodii chloride	2·79
Silica SiO_2	1·10
Sesquioxide of iron, FeO_3 ... } Alumina, Al_2O_3 .... }	0·32
Organic matter	Trace
Moisture	5·90
	100·00

The magnesia hydroxide ($Mg(OH)_2$) that is in the incrustation has been produced by the decomposition of the magnesia chloride at the high temperature to which the feed water has been raised. Its production is also partially due to the decomposition of the magnesia carbonate that has been formed by the chemical changes engendered by the reaction of the calcic carbonate in the soluble magnesia salts in excess. When we come to discuss the question of the chemical changes that have brought about corrosion of the boiler plates, we shall show that the amount of the magnesia hydroxide which results from decomposition of the magnesia chloride is a measure of the corrosive effect of this particular chloride on the boiler plates, as the following equation shows:—

$$MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl.$$

Consequently the water in the boiler will be more or less acid when the source of the magnesia hydroxide is magnesia chloride only. When, however, this hydroxide has been brought about by the intervention of calcic carbonate, then there is no such production of HCl, *e.g.*,

1st: $MgCl_2 + CaCO_3 = MgCO_3 + CaCl_2$.
2nd: $MgCO_3 + 2H_2O = Mg(OH)_2 + CO_2 + H_2O$.

From the above equation it will be observed that the presence of calcic carbonate in sea-water is more beneficial than injurious, because carbonic dioxide is less corrosive on iron than hydro-chloric acid (HCl).

The oxidation or corrosion of iron under water is by some authorities considered to be facilitated by the presence of CO_2 plus free oxygen and moisture. The following analysis of the incrustation formed in a marine boiler shows that the chief constituent of the incrustation is calcic sulphate, and the secondary constituent is magnesia hydroxide.

Analysis of Sea-water.

	Per cent.
Calcic sulphate, CaSO	84·27
Magnesia hydroxide $Mg(OH)_2$	7·04
Sand	1·94
Alumina, Al_2O_3 .... } Iron sesquioxide, Fe_2O_3......... }	1·10
Water, etc...........................	5·68
	100·00

The constituents of saline water, other than sea-water, depend on the nature of the source of supply, and geological strata through which it percolates. In the neighbourhood of mines

water contains a large quantity of saline bodies, chiefly sulphates, which have been brought about by the oxidation of pyrites and other sulphates. The following analysis shows the nature of the bodies found in a mine water in which sulphates are abundant :—

	Grains per gallon.
Calcic carbonate, $CaCO_3$	10·8
Calcic sulphate, $CaSO_4$	16·0
Magnesia sulphate, Mg_2SO_4 ...	20·4
Sodii sulphate, Na_2SO_4	73·6
Sodii chloride, NaCl	70·4

The presence of the calcic carbonate prevents such water being used. When no carbonate is present, the free sulphuric acid often exists in water of the above class, with consequent corrosion of the pumping machinery. The consideration of the life of a boiler and the cause of its corrosion, and also the consideration of the methods of condensing saline waters, processes of softening waters, of testing same for the presence and nature of foreign bodies, and applying bodies to prevent incrustation, require to be dealt with in separate papers.

PUMPS: THEIR CONSTRUCTION AND MANAGEMENT.

By PHILIP R. BJÖRLING,

Author of "Water or Hydraulic Motors." *

(*Continued from page* 21.)

DOUBLE-ACTING DIAPHRAGM PUMPS.

IN our last article we mentioned double-acting diaphragm pumps; as these are very seldom met with, it might be interesting to some readers, wherefore we have decided to give one example, which is illustrated in sectional elevation (Fig. 49). A and B are the top and bottom chambers of the pump body, between which is secured a sheet of flexible india-rubber C, dividing the pump into two parts; on each side of this india-rubber diaphragm are iron shields, D and D, secured to the pump-rod E, guided at both ends, one end of the rod being attached to the pump handle in the usual way. F and F are the suction-valves; A the suction-pipe; H the delivery-pipe; the delivery-valves being on a line with the suction-valves, are not shown in the illustration. The suction and delivery of the liquid is caused in the same way as in the single-acting diaphragm pump, and performed both at the upward and downward motion of the diaphragm.

ROTARY PUMPS.

The Rotary pumps exist in two forms, namely, single cylinder and double cylinder.

SINGLE CYLINDER ROTARY PUMPS.

There is such a great variety of designs of this class of pumps that it is difficult to know which is best to illustrate, because almost every one has some good features not existing in the other.

A pump invented by a Mr. Storey is shown in sectional elevation (Fig. 50). It consists of a cylinder A, provided with inlet or suction-branch B, and delivery-branch C. Within the cylinder revolves a cylindrical drum D, about an axis eccentric with that of the cylinder. The drum D is fitted with slides or paddles E, E and E, which have their outer extremities in contact with the cylinder, while the opposite ends revolve or roll round a conical pin F, occupying the central part of the cylinder, and fixed concentrically with it. The inner edges of the slides E are made conical to correspond with the pin F. The pin F is capable of adjustment in longitudinal direction, and by that means the paddles may be kept in constant and uniform contact with the cylinder face. The action of this pump is very simple, and it is reversible, which is a great advantage in pumping tar, for, by reversing the pump, the suction becomes delivery, and the thick, clogged tar can be forced out, hence clearing the pipes out before the pumping is commenced.

* E. & F. N. Spon., Ltd. 7*s.* 6*d.*

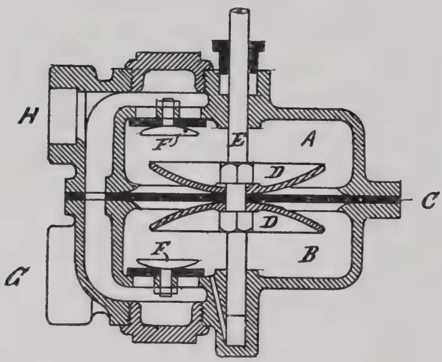


FIG. 49.

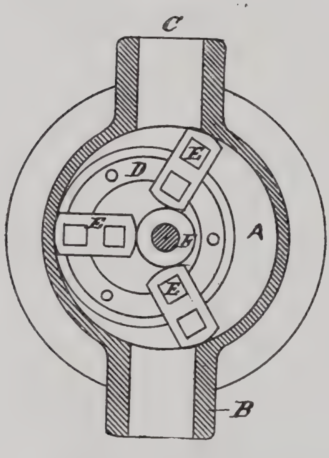


FIG. 50.—SECTIONAL ELEVATION OF SINGLE CYLINDER ROTARY PUMP.

DOUBLE CYLINDER ROTARY PUMPS.

The original inventor of this class of pump appears to be a Mr. Eve, who introduced it about the year 1825. The most modern and probably the best type is the one which is illustrated in sectional elevation (Fig. 51) and reproduction (Fig. 52), the latter showing a pump coupled direct to a vertical steam engine. It consists of a revolving piston A, sweeping out the cylinder B every revolution, the revolving piston dipping into the cylindrical drum C; the openings D and D are so arranged that the piston passes through without slip, back pressure, or undue friction. When the piston A moves round from the drum C, a vacuum is formed into which the water flows from behind, and is forced by the front face of the piston. The piston A and the drum C are geared together, and the pump can be driven either way; this is, as we have previously remarked, a very great advantage when thick liquids or semi-liquids are dealt with. E is the suction and F the delivery pipes, or *vice versâ*, according to the way the pump is running. J is the bed-plate, on to which the pump is secured.

The "Greinell" rotary pump is illustrated in cross-section (Fig. 53). This pump, at one time, was pronounced to be the perfection of rotary pumps, being invented by a baron, who made the most careful experiments and investigations, and the most elaborate means were adopted for testing each of the pumps, so as to get the proper proportions, and all parts as perfect as possible. It consists of a chamber or casing A, within which works two cylindrical drums, B and C, of equal diameter, running almost in contact with each other on parallel shafts, D and E. One of these drums, B, carries two radial vanes or blades acting as pistons, which, as they revolve, enter

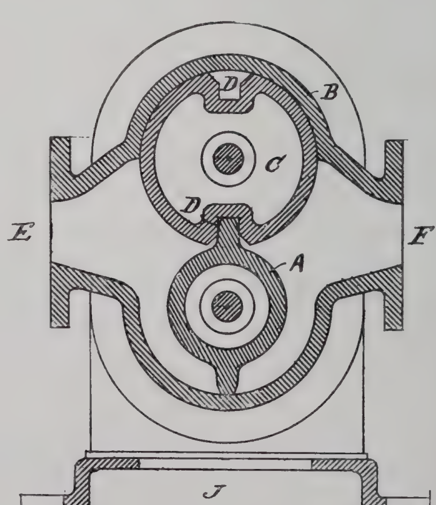


FIG. 51.—SECTIONAL ELEVATION OF DOUBLE CYLINDER ROTARY PUMP.

alternately into a groove of epicycloidal section, extending along the whole length of the other drum, C. The shafts D and E of the drums are geared together, so that the grooved drum C makes two revolutions to one of the bladed drum B, thereby enabling the single groove in the quick running drum to serve for two blades on the slow running drum B. The inlet branch F and the outlet or delivery branch G are arranged in such a manner as to prevent everywhere the same sectional area through the entire course of the water, in order not to impede its movements in any way during the passage through the pump. In consequence of the continuous motion of the stream of water, any foreign solid substances can be passed through the pump without occasioning either stoppage or a breakdown. These pumps are applicable in all cases where centrifugal pumps are suitable—for breweries, distilleries, oil works, sugar refineries, and contractor's use.

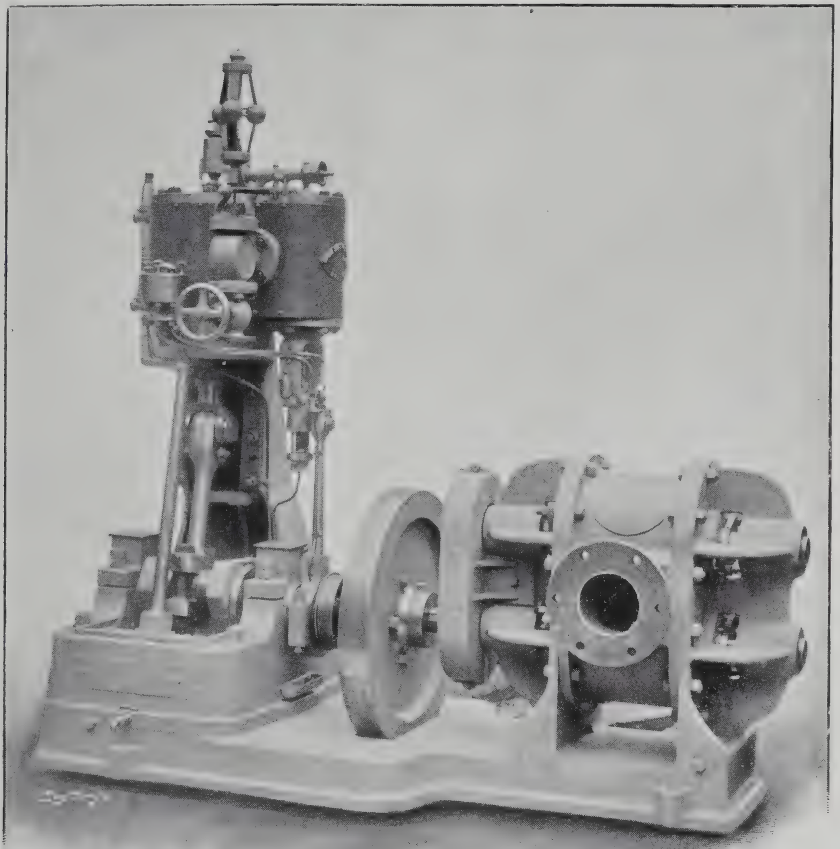


FIG. 52.—VIEW SHOWING A DOUBLE CYLINDER ROTARY PUMP COUPLED DIRECT TO A VERTICAL STEAM ENGINE.—MADE BY THE DRUM ENGINEERING CO., BRADFORD.

REVOLVING PISTON PUMPS.

This is a very unique pump; it is a combination of a rotary and a reciprocating pump. It is illustrated in cross-sections (Figs. 54, 55, 56, and 57), and

enlarged sectional plan (Fig. 58). It consists of an outer casing A, of a cylindrical form, carrying a suction-branch S and delivery-branch D; at one end of this casing is attached a cover C, having an internal crank E, and crank-pin F; at the other end a bearing or journal, in which the shaft B revolves; in the above-described cylinder A revolves a cylindrical drum with the shaft B attached, fitting the periphery. The drum is bored out cylindrically at right angles to the axis of the shaft, of as large diameter as can be conveniently given. Within this

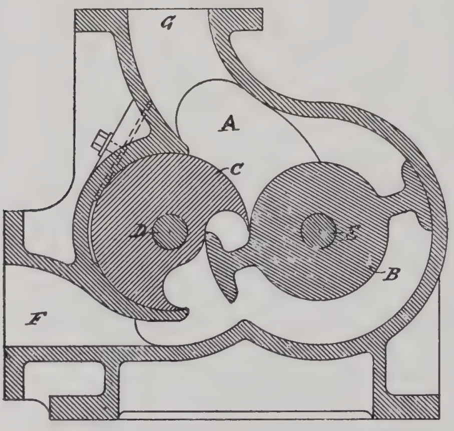


FIG. 53.—CROSS SECTION OF "GREINELL" ROTARY PUMP.

bore a piston G is fitted, which again is provided at right angles to its length by a cylindrical bore, and into this a piston J is fitted. The small piston has also an opening bored in it at right angles to its length, and parallel to the main shaft, into which the crank F is fitted.

For to explain the action of this pump it will be best to follow motions during one complete revolution. The main shaft with its drum B attached revolves on its own centre; the small piston J revolves on the fixed crank-pin centre, which, being eccentric to the shaft, represents one-half the length of the stroke of the pump piston J. These two revolving parts are connected by the main piston, which is free to move in one direction in its own cylinder, and in the other at right angles to it on the smaller piston, and is consequently capable of adjusting its motion on the circular path of the crank by revolving round it; in doing so it has a combined revolving and reciprocating motion, that is to say, the consequent effect is that at every revolution of the shaft and drums the main or large piston traverses up and down the cylindrical bore in the drum, and up and down the smaller piston at right angles to its own axis, revolving, at the same time, with the drum; and as, at each revolution, the alternate ends of these cylinders are presented to the suction and the delivery pipes, the contents of the two cylinders are transferred from one to the other without disturbing them. Suppose the pipe connection to the cylindrical casing to be in horizontal position, as shown in cross-sections—that is, S being the suction and D the delivery branch, and the crank-pin F vertically below the centre of the casing, the main piston J will be at the end of its stroke at the bottom, as illustrated in Fig. 54. Supposing the drum to revolve towards the left, as indicated by the arrow, at one-eighth revolution, the position of the two pistons will be as shown in Fig. 55; at one-fourth revolution, as indicated in Fig. 56; and at three-eighths revolution (Fig. 57). It will be seen that in Fig. 54 the small piston is drawing in on one side and discharging on the other; in Fig. 55 both pistons are in action; in Fig. 56 the large piston is in mid-position, drawing in and discharging, the smaller one having completed its stroke; in Fig. 57 both are in action.

ADVANTAGES AND DISADVANTAGES OF ROTARY PUMPS.

The advantages of rotary pumps are: — A continuous flow of water through the delivery-pipe; the small

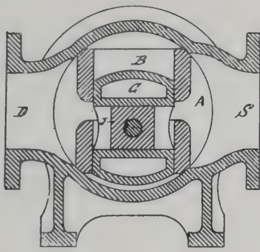


FIG. 54.

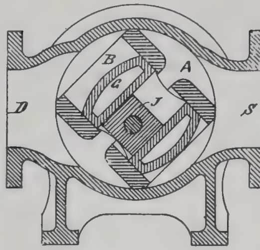


FIG. 55.

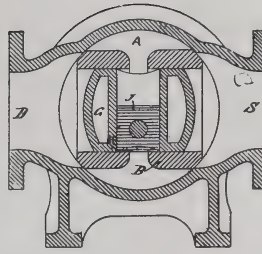


FIG. 56.

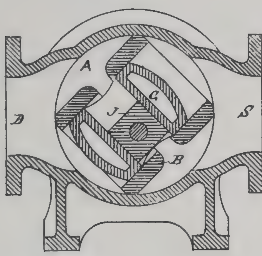


FIG. 57.

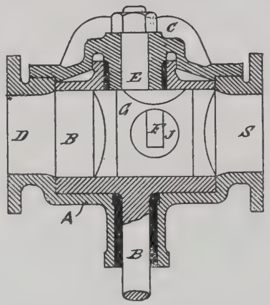


FIG. 58.—ENLARGED SECTIONAL PLAN.

FIGS. 54, 55, 56 AND 57.—CROSS SECTIONS OF REVOLVING PISTON PUMPS.

space they occupy in comparison with reciprocatory pumps; the reduced amount of friction; and the want of valves in the generality of rotary pumps.

The disadvantages are:—The high speed usually required, hence great wear and tear of the spindles or axles; also that they, as a rule, cannot be applied where there is a great depth of suction. Most of the rotary pumps cannot draw water from a greater depth than 12 to 14 ft.

CENTRIFUGAL PUMP.

When a large body of water has to be raised to a comparatively small height, the centrifugal pumps are undoubtedly the most economical, both as regards driving power required and first cost. They are inexpensive, simple in construction, not liable to get out of order, and are easily cleaned out.

When we compare centrifugal pumps with ordinary reciprocatory pumps, we find that for lifts above 20 feet the result

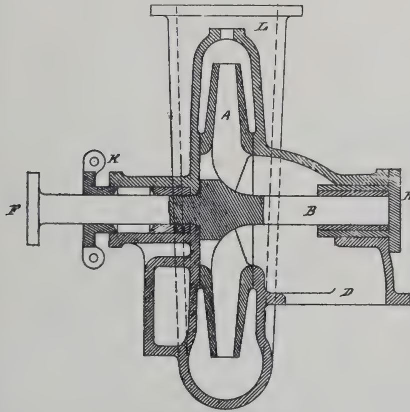


FIG. 60.—CROSS SECTION OF CENTRIFUGAL PUMP, WITH ADMISSION ON ONE SIDE.

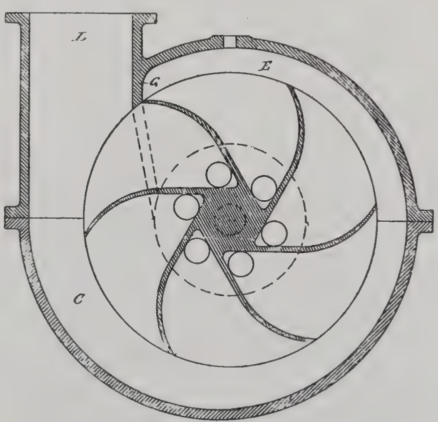


FIG. 59.—SECTIONAL ELEVATION OF CENTRIFUGAL PUMP WITH ADMISSION ON ONE SIDE.

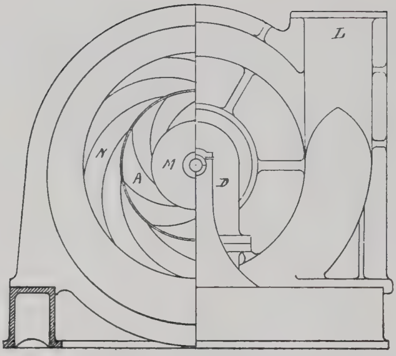


FIG. 61.—ELEVATION OF CENTRIFUGAL PUMP PROVIDED WITH GUIDE BLADES.

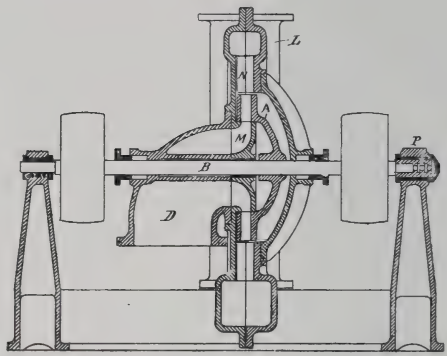


FIG. 62.—CROSS SECTION OF SAME.

is in favour of the reciprocatory pumps; under 20 ft. to about 5 ft. the two classes are equal; but for 4 ft. to 5 ft. lifts centrifugal pumps have a most decided advantage.

The most advantageous application of centrifugal pumps is where the lift required is both moderate in its maximum amount, and variable, as when pumping against tidal waves or discharging graving docks. In both cases the lift is very small, and varies irregularly to its maximum. Under such circumstances, a centrifugal pump possesses peculiar advantages, for it keeps working at its ordinary speed; and with the employment of a nearly constant amount of motive power, it has a faculty of adapting itself to the varying lifts.

CENTRIFUGAL PUMPS WITH ADMISSION ON ONE SIDE.

A centrifugal pump of this class is illustrated in sectional elevation (Fig. 59), and cross-section (Fig. 60). In this pump D is the suction-branch, through which the water enters into the impeller A; C is the bottom part of the casing, E the top part of the same, which latter must be removed when access to the impeller A is required; B is the spindle, which, in this example, is cast in one with the impeller, but in large sizes it is made to pass through a

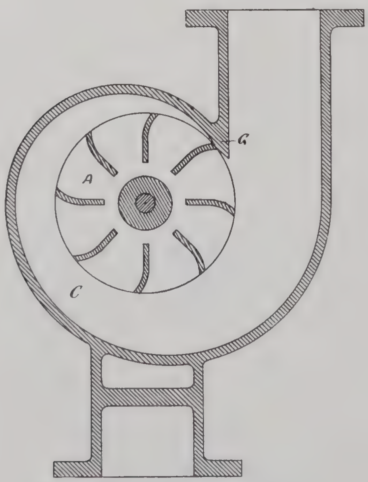


FIG. 63.—SECTIONAL ELEVATION OF CENTRIFUGAL PUMP, WITH ADMISSION ON BOTH SIDES.

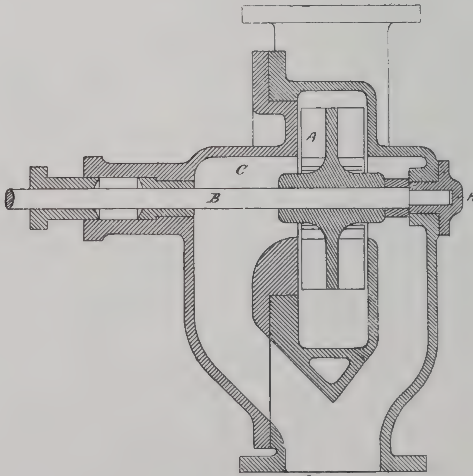


FIG. 64.—END VIEW OF SAME.

boss in the impeller or fan. The spindle is at one end carried in a stuffing-box and gland K, and at the other end by a solid-ended bush H; the bush and stuffing-box are lined with *lignum vitæ*. The vanes in the impeller are of the combined radial and curved form, as shown in Fig. 59. The casing is scroll-shaped, and provided with a cross-piece G, to prevent the water from rotating in the casing. L is the delivery-branch.

In the example before us the impeller is 25 in. diameter; the inlet and outlet branches 8 in. diameter. The width through the impeller at the periphery is $1\frac{1}{4}$ in.; at the central opening 3 in.; the spindle is $2\frac{3}{4}$ in. diameter. The whole of this pump was made of gun-metal $\frac{5}{16}$ of an inch thick in the casing, and the vanes or blades of the impeller $\frac{3}{8}$ of an inch thick at the centre, and $\frac{3}{16}$ of an inch at the periphery. A coupling F was cast on the spindle, therefore the gland K was made in halves and bolted together, as shown in Fig. 60. An objection exists in all centrifugal pumps having inlet at only one side, namely, that the position of the inlet pipe cannot be changed to suit circumstances, which frequently necessitates several bends; these latter are very objectionable in suction-pipes for any class of pump—especially centrifugal—where the depth is great, because the bends increase the friction considerably.

It has been recommended by some engineers to provide guide blades in centrifugal pumps. A pump of this description is illustrated in elevation (Fig. 61) and cross-section (Fig. 62). The water ascends up the suction-pipe D, and is gradually guided into the revolving wheel or impeller A, by means of the guide blades M; from the impeller it is projected by centrifugal impulse into the vanes of the concentric guiding-wheel N. In this case the guide blades M are fixed, but they are sometimes made adjustable, so as to regulate the quantity of fluid conducted into the pump. In such cases, and with centrifugal water pumps, it replaces the foot valve, and serves to fill the pump, also allowing such pumps to be placed direct into the outlet pipe without any outer casing. The directing plates are shaped to the section known as the "contraction curve." The guiding-wheel N is fitted concentrically to the outer periphery of the impeller A, and the proportions and directions of the series of cells of which the fixed wheel casing consists are adapted to the absolute velocity of the issuing fluid. The fluid flows out of the cells in a radial direction when no eccentric outer casing is applied, and more tangentially when no such an eccentric casing is used, as illustrated. L is the delivery-branch,

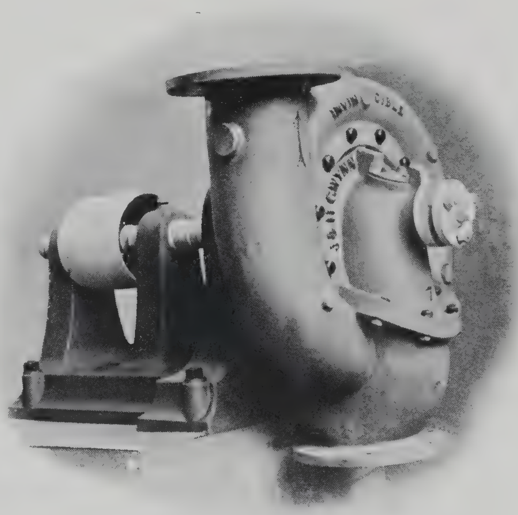


FIG 65.—VIEW OF "INVINCIBLE" CENTRIFUGAL PUMP MADE BY J. AND H. GWYNNE, LTD.

B the spindle, and P is a thrust-bearing to take the stress due to the one-sided admission.

The last-described pump is sometimes placed horizontally in an iron or brick well, the outlet for which is placed at the lowest level to which the water in the outlet channel is likely to fall. The pump is hung on its spindle by a

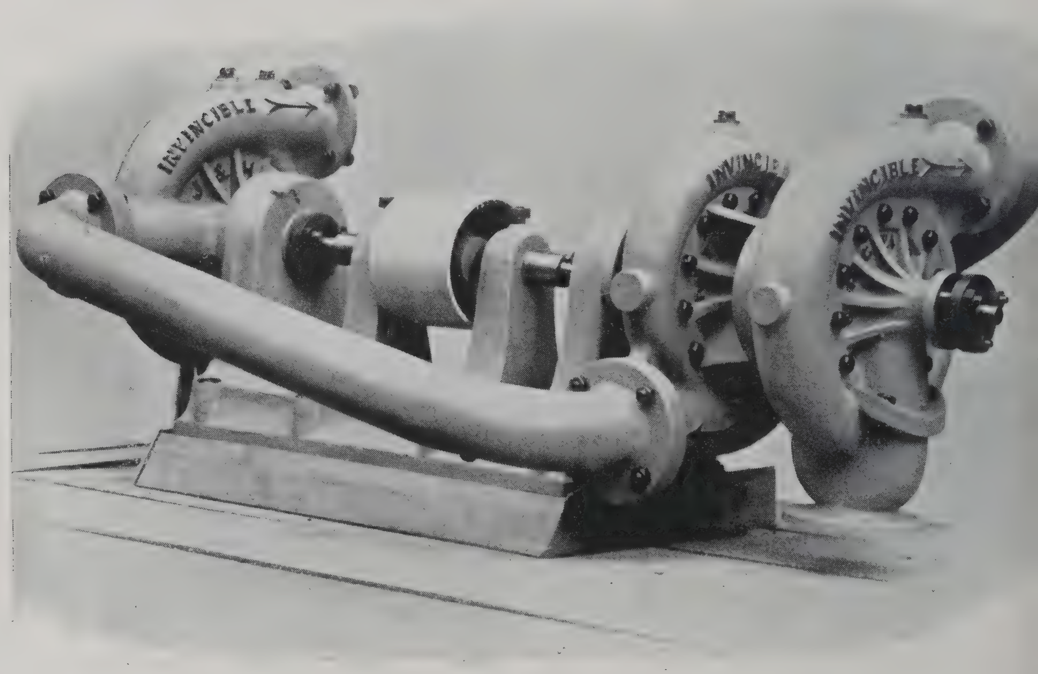


FIG. 66.—VIEW OF A TRIPLE SERIES OF "INVINCIBLE" CENTRIFUGAL PUMPS MADE TO DELIVER WATER TO A HEIGHT OF 200 FT.

gun-metal bearing always accessible; this of course does away with a footstep. All the bearings of the different parts have conical-shaped seats, and the impeller can be taken out and replaced without emptying the pump-well. No suction or delivery pipes are used. The outlet from the well is fitted with a self-closing back-pressure or retaining valve, to prevent the water from flowing back when the pump is standing.

CENTRIFUGAL PUMPS WITH ADMISSION ON BOTH SIDES.

An ordinary pump of this class is illustrated in sectional elevation (Fig. 63); and end view (Fig. 64). The impeller A is provided with a mid-feather, so as to prevent the two streams of water, one entering from each side, from eddying when they enter the impeller. It has eight arms or vanes cast on. These arms are straight part of their length, only curved at their extremities. The spindle B works in a stuffing-box and gland at one end, and a solid-ended bush H at the other. The pump body C is scroll-shaped, so that the impeller almost touches the body at the point G, so as to dispense with the usual cross-bar. It will be noticed that the left-hand side of the body is made into a cover for easy access to the impeller.

Fig. 65 illustrates one of Messrs. J. and H. Gwynne's, Ltd., ordinary "Invincible" centrifugal pumps. They afford great facility for the inspection of the internal parts; hand holes with bayonet joint covers are provided at the top of the suction inlets, so that the interior may be easily examined, and any foreign matter removed. In addition the sides of the pump may be taken off and the impeller and spindle removed when necessary, without disturbing a single

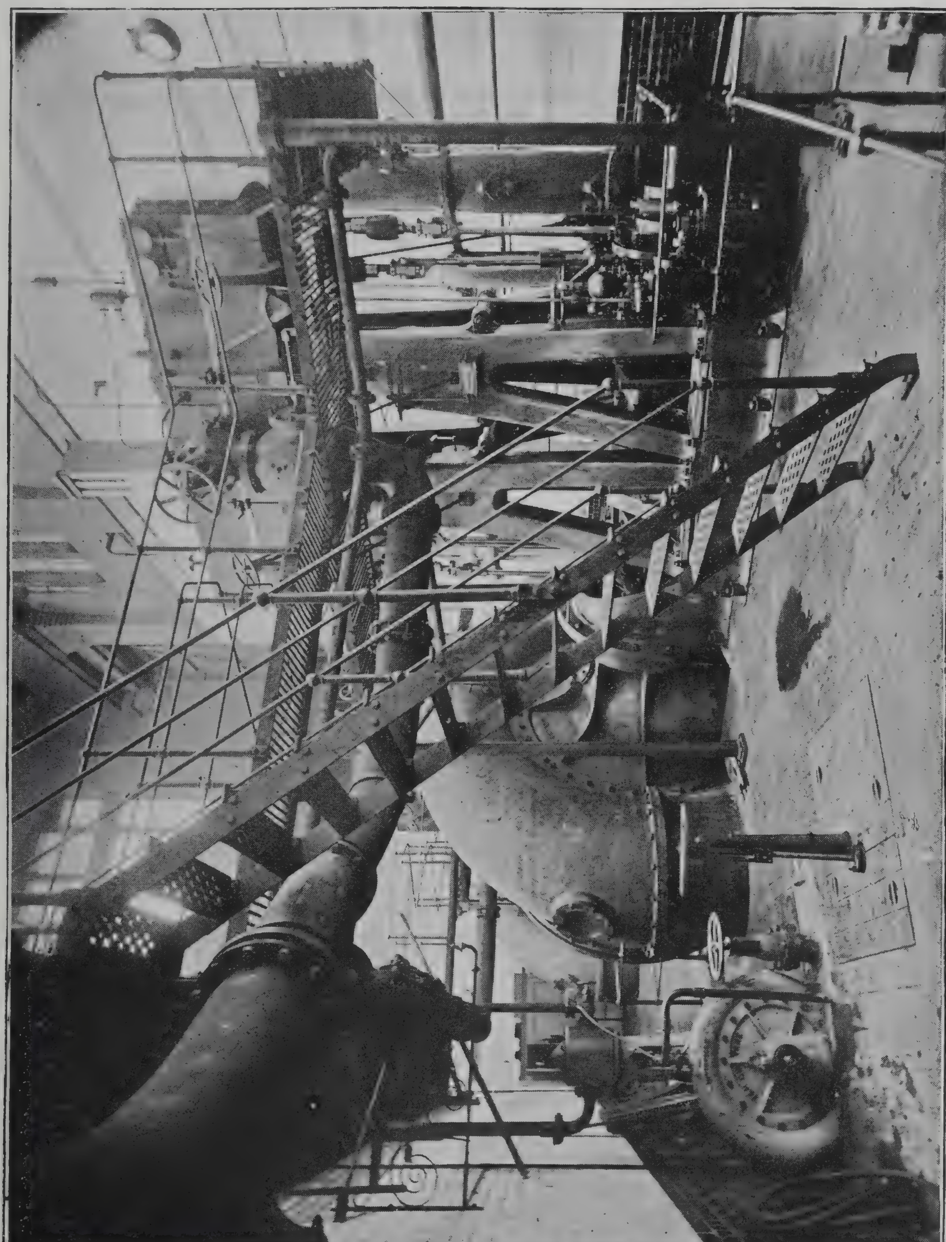


FIG. 67.—VIEW OF "INVINCIBLE" PUMPS AT THE CANADA GRAVING DOCK, LIVERPOOL.

joint either in the suction or delivery pipes. The pump is arranged to swivel on the bed-plate, so that suction and delivery branches may be placed at any angle by simply slackening a few nuts. The illustration shows the ordinary right-hand pump with vertical branches, double standard, and fast pulley.

For heads over 80 feet these pumps are arranged in series, as illustrated in Fig. 66; in this case it is a triple series, made to deliver water to a height of 200 feet. The pump to the extreme right hand in the illustration delivers its water into the centre pump, that pump delivers into the third pump, and that one forces the water to its destination.

The "Invincible" pumps, at the Canada Graving Dock at Liverpool, are illustrated in the reproduction of a photograph (Fig. 67). There are three 51-in. "Invincible" double-cylinder jet condensing Centrifugal Pumping Engines for emptying this, the largest dock in the world. The engines combined are 2,200 Indicated Horse-power. During the test the pumps delivered 3,226,648 cubic feet in four hours and forty minutes.

These Centrifugal Pumps are also used with great advantage for Dredgers for recovering gold, etc. They raise sand and gravel containing precious stones, auriferous, and metalliferous deposits from beds of rivers, lakes, etc. In such cases they are sometimes placed in a punt, together with all the driving and warping machinery. The lateral movements of the suction-pipe, and raising and lowering of the same, also the warping of the punt, are under the control of the operator. The suction-pipe is fitted with patent mouth-piece, and "stone or solid" trap; when the latter is adopted, any solids that will pass up the suction-pipe are lifted; at other times the machinery is fixed on land, the suction-pipe only being movable.

(To be continued.)

Philip R. Björling

THE ECONOMIC ASPECT OF STEAM GENERATION.

By W. FRANCIS GOODRICH, A.I.Mech.E.

(*Continued from p. 28.*)

MACHINE FIRING.

IT is now nearly fifty years since mechanical stokers were first introduced. As might reasonably be expected, the first productions were very crude and inefficient in the extreme, and for the economic and powerful generation of steam the machine stoker of the middle of last century would cut a sorry figure if pitted against its prototype of to-day.

Strange to say, the improvement in the mechanical stoker has not been a gradual process such as one might expect would be the case; real solid progress has practically been confined to the past ten or twelve years only, and, to be candid, even some machine stokers of to-day bear a remarkable family likeness to those made thirty and even forty years ago.

What has been the cause of this lethargy, this hesitation in improvement? It is really difficult to adduce any reason except that the older makers of mechanical stokers have been possessed by the same contempt for improvement which is at length asserting itself by the many decadent industries in this country and the simultaneous triumph of the foreigner.

At the outset it may be well to carefully consider what advantages, if any, machine firing possesses over hand firing. Is it more efficient? Is it more economical? Is the record of machine firing in the past as good as that of hand firing? If not, then why not, and what of future prospects?

These have been and are still much debated questions—in my own opinion there is a field for both. Some may say that is evasive, or tantamount to "sitting on the fence," so I will endeavour to explain my reasons.

To a large extent in the past machine stokers have failed primarily because they have been fitted to work under such conditions as have rendered success impossible. A steam user is troubled with an inefficient boiler owing to a deficiency of chimney or natural draught; he is persuaded to apply machine stokers, with the result that he effects no improvement, but as a matter of fact is even worse off. Why? Simply because what has been sold to him as a remedy was a quack for such a case—he wanted draught, he bought stokers.

Of course the remedy in such a case was either improved chimney draught, or what would no doubt be cheaper and more practicable, forced draught, but instead the shadow was purchased, the substance not recognised until too late.

Hundreds of stokers have been dismantled and thrown on the scrap heap which, strictly speaking, should never have been erected at all; in the majority of cases these have been replaced by forced draught after much disappointment and vexation.

Unfortunately the general result of such failures is to produce a great

number of steam users who for ever after are hostile to machine firing; they condemn stokers wholesale, failing to recognise the fact that their existing conditions were not favourable, and that they failed to locate their own want.

But let us not forget that the steam user is not entirely to blame for his attitude. One serious factor in thus stifling enterprise is the vendor or maker of the stoker, who either did know or should have known that he was not selling a remedy, but instead was deliberately taking a mean advantage of ignorance.

Thus mechanical stoker makers largely have themselves to thank for throttling enterprise, and for producing a large body of steam users in this country who are bitterly opposed to machine firing; they are generally suspicious of all so-called remedies or improvements hereafter. They sought an improvement but got "no forrarder," and many require very considerable persuasion to move again.

Now as to the advantages of machine firing over hand firing, for there are advantages which cannot but be obvious to all who study the question at all. In the first place, the clockwork regularity of the machine stoker is an advantage—one cannot make a man work like a machine—it is quite impossible to get a man to perform the same mechanical and monotonous grind which is the function of the machine fired apparatus.

If it were possible to persuade a man to do his work with the same precision and regularity, many of our present troubles, so far as hand firing is concerned, would disappear, but as that is quite out of the question generally speaking, a good machine stoker working under proper conditions is really a very excellent device.

A further advantage over hand firing is the fact that the fires have not to be cleaned, causing stoppage, cooling down of gases and loss of steam pressure—a distinct advantage. With a regular feed of fuel and automatic cleaning of fires, the stoker working under favourable conditions possesses advantages which must tend to greater economy and efficiency than is possible with ordinary hand firing.

I say ordinary hand firing because where forced draught is employed with hand-firing and a first-class fireman, I believe most ordinary machine stokers could be beaten, but it is scarcely necessary to add that 99 out of every 100 firemen are not first-class men, and it is the exception rather than the rule to find one doing really good work.

With regard to the record of mechanical stokers in this country, one serious reason has already been adduced accounting for a large number of failures, but there is another and perhaps more powerful reason, and it is this. The machine stoker of the past has been for the most part a poor production in many ways; here I refer principally to its construction and capabilities.

To take the question of construction first, if we compare the original natural draught coking stoker and the stoker of the same type to-day, what do we find? Practically the same ponderous construction, an ugly and unnecessarily heavy piece of work, the movements producing alternate clank, groan, and sigh, very little latitude in working, either as to speed of fuel delivery or travel of bars.

But when one considers for a moment the lack of elasticity in travel and feed is not to be wondered at so much, for it is a natural draught stoker; that is to say, it is limited to the chimney for the rate of coking and rate of combustion, and little could be gained in arranging such a machine to travel or feed beyond the chimney capacity as to rate of com-bustion.

Steam users would do well to bear in

mind that no natural draught mechanical stoker yet invented can burn one pound of fuel more per hour than could be burned with the same chimney if the fuel was hand fired. If this simple, logical, and incontrovertible fact was borne in mind, much vexation and annoyance might be averted.

The coking stoker, with all its imperfections, is generally admitted to be the most perfect smoke preventer yet produced, and up to this time nothing has been designed which can do better in that respect, while the vast majority of "guaranteed cures" and so-called panaceas fall very short of its record in that direction, at any rate.

The reason of such success is not far to seek; it is also powerful and conclusive. The coking process is a natural method of smoke prevention; the fuel, being gradually pushed on to a coking-plate immediately inside the fire-door, there ignites and cokes into a mass; the hydrocarbons, being expelled, have to traverse the whole length of incandescent fire, and are thus effectually dealt with.

Such a process is naturally a slow one under ordinary conditions, and is strictly limited to the chimney draught, both as to rate of coking and rate of combustion. There is your limit, and hence how can it avail you, as already pointed out, even if you have a stoker which can be regulated to feed quicker than your chimney can coke and burn the fuel? Your stoker may be adjustable over wide limits, both as to feed of fuel and travel of bars, but it is useless to ignore the fact that the vital factor, your chimney—your natural draught—governs all other factors, and will bring you to a dead stop.

Here in London we have hundreds of natural draught coking stokers, and many burn ridiculously small quantities of fuel. When the steam user has required more steam, and still a clean chimney, his move has been again and again to put down a new boiler and stokers, but on the same chimney. Time goes on, and the chimney is "crowded," less fuel is burned per square foot of grate all round, and that fuel is burned less thoroughly, less steam is obtained, efficiency is reduced all round. The continued outlay has only had the effect of promoting increased inefficiency; the remedy which was sought was not obtained.

Why put down new boilers at all, when your existing boilers are working so much below even their rated capacity? Put this question to one of the old school, and he will tell you that he will not have his boilers forced. One hears this remark again and again, but many who utter it have a strange idea as to what forcing really is. Certainly the remark has no true application to a boiler working within its rated capacity, and equally certain it is that hundreds of boilers in London alone, fitted with ordinary coking stokers, are working a long way within their rated capacity.

Let us take a standard "Galloway" boiler, 30 ft. by 8 ft. The makers rate this to give an evaporation of 7,800 pounds of water per hour, under presumably good average conditions, but in how few cases is this being done with the ordinary coking stoker even under the very best conditions. My own experience has been that such boilers, with ordinary coking stokers, as a rule evaporate between 500 and 600 gallons per hour, and an evaporation of even 400 gallons per hour is by no means unknown.

Here you have the general position of matters with the ordinary coking stoker. You want a clean chimney? Very well, you can have it; you might have had it a quarter of a century ago, secured by precisely the same means, but you must be prepared to accept low boiler duty with smokelessness if

your choice is the stoker we have been considering.

This is one reason why machine firing has not been more extensively adopted. Here in London and our large cities land is far too valuable to be encumbered with unnecessary boilers, put down to give a duty so short of even the rated capacity.

Times are changing; some of our largest steam users decline to put down new boilers until they are getting good duty out of existing boilers, and rightly too. Central lighting stations have tried such coking stokers and small bituminous fuel with a view to economy. At the peak they have tried to force the stoker. Excessive quantities of fuel have been rushed through the fires by the aid of tools and plenty of that human element which the stoker was said to render unnecessary. Little good is done by thus "murdering" fuel when you are bound by your chimney draught. Plenty of smoke is made, the ordinary coking stoker being a terrible offender in this respect if not allowed to pursue its natural course.

It is for this reason that to-day we find central lighting stations largely employing expensive Welsh coal, and during the past few months, owing to the rigorous enforcement of penalties for smoke, it has been almost pathetic to read some of the excuses in police court proceedings, owing to the difficulty at times in getting Welsh coal.

I say most emphatically that we are in a very bad way indeed if we are not independent of Welsh smokeless coal. If this fuel is a vital necessity for steam raising, then our practice is indeed miserably poor.

What credit attaches to an appliance which will burn smokeless fuel without smoke? The reader will no doubt consider this a strange question, but I am constrained to put such a query when I see an inventor point, with swelling pride, to his patent on a boiler burning Powell Duffryn Welsh steam coal or Great Mountain or other anthracite. He positively assures the steam user that he can keep him out of the clutches of the law if he will religiously burn such fuels.

Having now considered the coking stoker of the past, we will pass on to the sprinkling type of stoker. At the outset, let it be carefully borne in mind that this type is distinctly inferior to the first-named as a smoke preventer, and where absolute smokelessness is demanded, it must not be seriously considered. To be perfectly fair, however, as a steam raiser it is in advance of the old coking type. For that reason it has found much favour in many parts of the country.

Having said this, we are once again brought face to face with that determining factor, draught, and only within such limits as the chimney will allow is this type of stoker useful, as will, I think, be obvious. A serious fault of the sprinkling stoker—which need only be just mentioned here, as it is universally admitted—is the liability to quickly choke the flues with fine dust and small fuel. If the chimney be a powerful one, this trouble is only aggravated, as quantities of very fine fuel and dust are rained out of the chimney-top, constituting a serious nuisance.

Many argue nowadays that machine stokers are only labour-savers when fitted to a range of boilers and also fed by a system of conveyors, but I am inclined to think that even for a single boiler machine firing has much to recommend it, and that a reasonable saving can be effected, providing that large hopper capacity is provided; the man is left free for giving attention to other work outside the boiler-house. The clinker-pit has to be cleaned out periodically, the machine lubricated, boiler feed watched, and hopper filled

at intervals. Such constant attention as hand firing demands is not wanted; the efficiency will be higher, and smoke prevented. I now refer, of course, to a first-class modern machine stoker. Naturally the economy will be much greater in a large boiler plant, arranged with elevators, conveyors, and also a system of conveyors for removal of clinker and residue; and a modern, well-arranged, and well-managed installation reduces labour to the minimum, effecting an extraordinary saving over hand firing.

Before proceeding to deal with the more recent developments in machine firing, I should be shirking a duty to both stoker makers and steam users alike if I omitted to allude to the repair bill and the treatment of the machine stoker, which, to a large extent, determines the size of the repair bill.

Without any fencing, I will at once say that too often stokers do not receive that careful treatment which conduces to minimise wear and tear; too often it is not recognised as a machine, being consistently neglected, and at times roughly handled. If steam users only knew how the repair bill is kept down in works where the stoke-hole is under strict supervision, they would know what laxity costs them.

Wear and tear must always be inseparable from the machine stoker, even under the very best of conditions, but it can be reduced to a very respectable percentage with reasonable care. Management is so scarce in many stoke-holes that, so long as sufficient steam is provided, matters run smoothly. The repair bill to stokers may be a heavy one, but the steam user does not suspect his men or the management, but instead condemns Blank's Stoker, and threatens to remove same.

There you have one side of the matter; now for the other. And it is this: many stokers are badly designed, badly constructed, and badly fitted, and, however good their treatment may be, a long repair bill will as surely follow their adoption as night follows day. Again, many stokers cannot be lubricated—a serious but common defect, causing endless trouble and frequent stoppage.

The application of the ordinary machine stokers in cases of very deficient chimney draught is always responsible for abnormal wear and tear, mostly owing to local over-heating caused by sluggish draught.

Now, as to recent developments in machine firing, the reader will have gathered from my remarks, both as to various systems of hand firing and machine firing, that draught is the vital factor in steam raising. Very well, if we are to profit by past experience and failure, we must be quite sure of the draught.

What we want, then, to repair the mistakes of the past, and to prevent such trouble again, is a stoker which is not limited by the chimney, but independent of it, be the chimney good or bad.

Such a stoker is made, and has been in successful use for some three years past now. It possesses all the advantages of the old coking stoker, but its disadvantages have been carefully avoided. The workmanship is of the very best, the efficiency very high indeed, and as a powerful steam raiser it stands unapproached.

To save any misapprehension I will at once say that I have an interest in this innovation.

About a year since, in these columns, I ventured to suggest that the stoker of the future would be a Forced Draught Stoker. At that time some suggested that the wish was father to the thought. In has been truly said that "imitation is the sincerest form of flattery," of which I am reminded when one of the oldest

makers of ordinary coking stokers in this country commenced to experiment with forced draught added to their stokers. I make no further comment; a straw will show how the wind is blowing.

Whatever may be said to the contrary, the fact remains that to-day the two mechanical stokers which are giving the best results are both artificial draught stokers, and between these and the natural draught stokers a wide gulf is fixed so far as results and efficiency go.

During the past two years we have been invaded by quite a number of American stoker makers, all claiming to be the best, and also to be able to easily improve on our best British practice. We have not yet seen the improvement; we have not yet even seen our best British practice approached. What may succeed with some American fuels will not of a necessity succeed here with our fuels. We have certainly moved slowly in this country, as, indeed, we do in most matters; but in the economic generation of steam from our own fuels, I venture to think that our best practice is such as to be unattainable by any American stoker or foreign apparatus for some time to come.

W. Francis Goodrich

SOME NOTES ON AMERICAN FOUNDRY PRACTICE.

By J. W. JACKMAN.

IN these days, when the stress of increasing competition, both by America and Germany, is bringing home to the British manufacturer the urgent necessity of adopting the most up-to-date machinery and methods to cheapen the cost of production and increase the output of his shops, much attention has been and is being given to the adoption of automatic machinery, and the standardising of patterns, so that machine shop practice is now much in advance of the methods of ten years ago. It is a curious fact, however, that while fully awakened to the necessity of adopting modern tools in the machine shop, the question of improving the foundry has been comparatively neglected in this country, and the tools and appliances of forty years ago are still considered efficient enough, and practically no improvement has been made over the methods then in general use. In America there is perhaps no department of the works which has had such careful attention and where so much improvement has been made. A few instances are sufficient. In this country little attention has been paid to scientific cupola practice. Any foundry foreman considers himself competent to erect an efficient cupola. "Take an old boiler shell, set it on end, and we get the best possible results

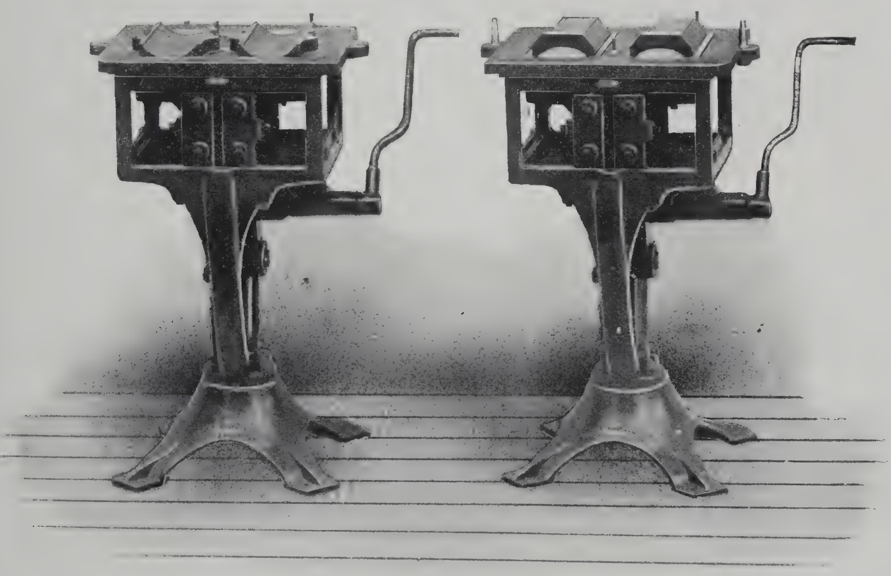


FIG. I.—A PAIR OF "PRIDMORE" SQUARE-STAND MACHINES, 10 IN. BY 12 IN., MOUNTED WITH RAILWAY JOURNAL BRASS PATTERNS

both in hot fluid iron and in fuel economy," is a remark that has been more than once seriously made to the writer by some self-sufficient, half-educated foundryman. Compare this with American practice, where, in all the largest and best equipped foundries, the home-made tinkered-up cupola is never found—there it is considered wiser to take advantage of experts' knowledge, and cupola building is as much a matter of specialised knowledge

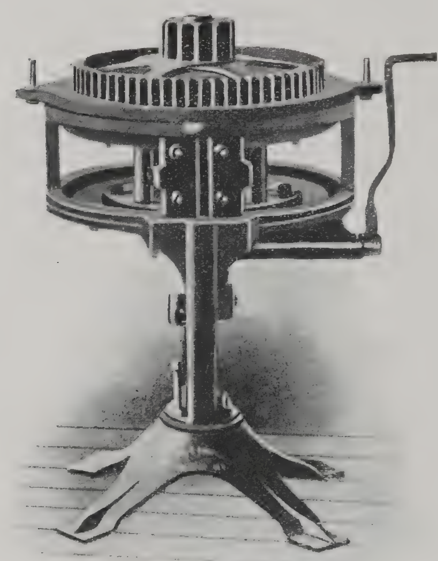


FIG. 2.—A "PRIDMORE ROUND-STAND MACHINE, 16 IN. DIAMETER, WITH GEAR AND PINION PATTERN.

as the making of the finest automatic tool—and in consequence the writer has found on visiting a large number of representative foundries in the States that the "Whiting" cupola, which has the best reputation there as a practical scientific cupola, is nearly everywhere being used. Another instance—how common it is here to see labourers carrying up to the charging platform both fuel and pig iron, or slowly hoisting the charge by means of some ancient and slow working elevator. Contrast this with the quick, economical labour-saver, the pneumatic elevator, which is now everywhere in use in the States, and which reduces enormously the cost of handling the charge. It costs more than the old method, but it pays, and pays handsomely, for the initial outlay. A most noteworthy instance, too, of the improvements in foundry practice which have been adopted in America is in the use of moulding machines in the foundry. Modern machines of this kind have been evolved there because of the need for them having been more acutely felt, on account of the far larger number of foundries wholly engaged in producing repetition castings. Foundries of this class have in the past been comparatively few in this country, but we are now waking up to the necessity of specialising in our machine shop, and standardising our patterns, and the manufacturing engineer finds that it does not pay him to make it his boast that he is ready to make anything, but is learning to concentrate his energies on a few specialities. It follows that his foundry will naturally become a repetition foundry, and economy in producing many moulds from the same pattern will become a question worthy of much consideration.

Fifty years ago moulding machines of a kind were being used here in certain foundries doing repetition work, making castings for agricultural implements, spinning machinery, etc., and these fifty-year-old machines, slow, inaccurate, and costly, are still being used, and little or no effort has been made to improve on their results. In the United States the modern moulding machine has been slowly but surely evolved from the primitive machines above referred to—the greater amount of repetition work has been the incentive to make improvements, and many inventions have been made, tried, and discarded before the present type of machines has been finally adopted.

The experience of one great American

foundry—perhaps the greatest foundry in the world where light castings are produced—may be cited as illustrating the development that has taken place. This is the McCormick Harvesting Machine Company, of Chicago, which has a present output of grey iron castings alone of some 400 tons per day—of the light class used in agricultural machinery—as well as 100 tons of malleable castings.

Some ten years ago there was much stir made among foundrymen in the States by the introduction of a new class of moulding machine which was to revolutionise the industry, and which appeared likely to do so, from the experiments which were made. This machine —a highly complicated and highly ingenious device—was designed to ram the sand moulds mechanically by means of a head or plunger operated by compressed air, and thereby save all the hand ramming, and so produce the moulds much more rapidly than had previously been possible by hand work.

A complete plant of this machinery was installed by the McCormick Company at the cost of some £26,000, and their staff of moulders was replaced by labourers, as only a few expert mechanics were stated to be required to superintend the machines. Unfortunately, however, the expected results were not obtained. It was true that the labour costs were less through the moulders being dispensed with, and the moulds were produced more quickly, but the machine ramming was found to be unsatisfactory, and in no way equal to the old methods of hand ramming, because the machine could not do what expert moulders had previously done, regulate the density of the sand according to the requirements at each part of the mould, and the consequence was that many of the castings were defective and useless. Another cause of bad castings was that in order to withdraw the patterns from the sand it was necessary to either rap or vibrate the pattern plate, thus frequently

FIG. 3.—A PAIR OF 30 IN. "PRIDMORE" MACHINES MOULDING MOWER WHEELS IN THE McCORMICK FOUNDRY.

breaking down sharp corners or pockets in the pattern, and necessitating patching the moulds, for which expert moulders were, of course, required. Beyond these disadvantages it was found that the machines were frequently breaking down, and needing repair, on account of not being suitable for work in the rough conditions inevitable in a foundry, with the dust and sand ever present to damage their working parts. This failure of so costly an experiment led the technical expert of the McCormick Company, Mr. Henry E. Pridmore, to experiment afresh on a type of machinery which should give the required results and not possess the manifest disadvantages of the machinery which had proved inefficient. The result was the development of a machine which proved entirely successful, and hundreds of the "Pridmore" machines are now at work in the McCormick foundry, operated by unskilled labour, with the result that a saving of no less than 73 per cent. on the cost of moulding and pouring has been made by the adoption of this machinery.

A short description of the "Pridmore" machine, which has achieved such results, will doubtless be interesting to the British foundryman. The principle of the machine is simplicity itself; it consists of an outer frame on which the plate carrying the moulding box rests, and of an inner or descending frame which carries the pattern, and which is raised or lowered by means of a lever. The patented mechanism is most simple in construction, and has been designed with a view to the hard wear to which it must be subjected in a foundry, so that no part of the machine is liable to get out of order.

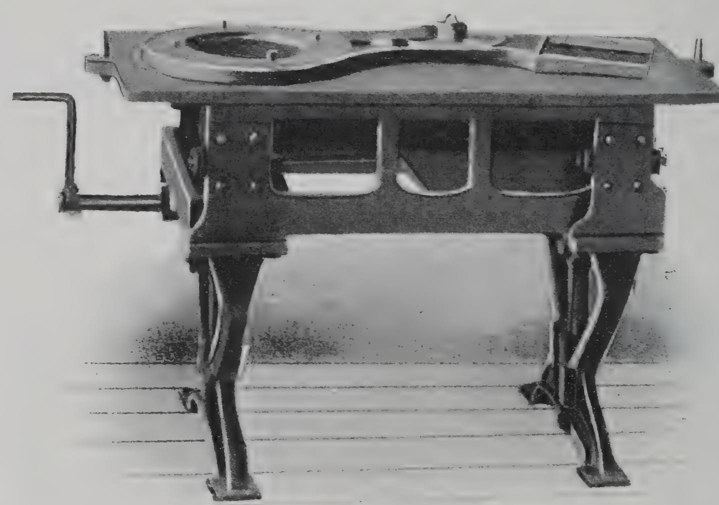


FIG. 4.—"PRIDMORE" DOUBLE STAND SINGLE SHAFT MACHINE, 16 IN. BY 24 IN., WITH RAILWAY SIGNAL ARM PATTERN.

The pattern is raised into position for the sand to be filled into the box, the sand is then filled in, rammed by hand, and the pattern is drawn down through the stripping plate, which rests on the outer frame of the machine, without any rapping being required to cause it to leave the sand, thereby insuring clean, true, sharp moulds, from which accurate castings are the result.

The machines are made in several different types but all on the same

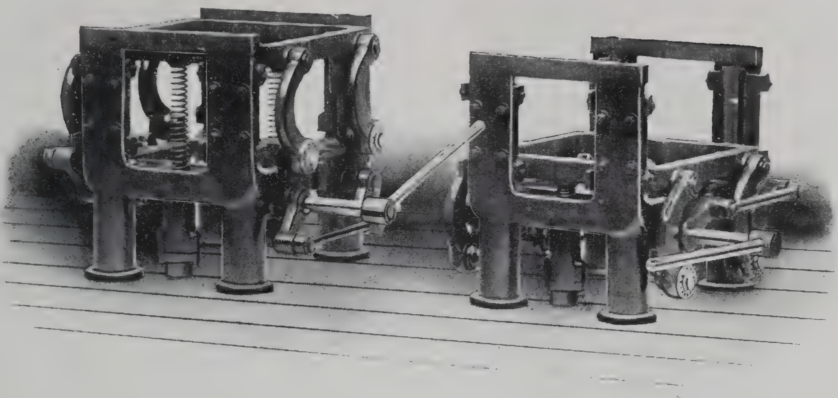


FIG. 5.—18 IN. BY 18 IN. HEAVY DOUBLE SHAFT MACHINES, SHOWING PATTERN CARRYING TABLE IN BOTH POSITIONS.

principle, and illustrations of the types are given.

The small stand machines, both square and round (see Figs. 1 and 2), are suitable for all small light patterns or gates of patterns ranging from 10 in. wide by 18 in. long or 10 in. in diameter, to 18 in. wide by 30 in. long or 18 in. in diameter. This type of machine is designed for patterns requiring a draw up to $4\frac{1}{2}$ in., and the amount of draw required is adjusted to a nicety by a set screw in the base of the machine. This class of machine is designed to be easily moved, and in operation two machines, one mounted with the cope pattern, and the other with the drag, are operated one each side of a central heap of sand running the length of the foundry floor, with the drag and cope boxes stacked parallel with the sand (see Fig. 3). A labourer operates each machine, and the

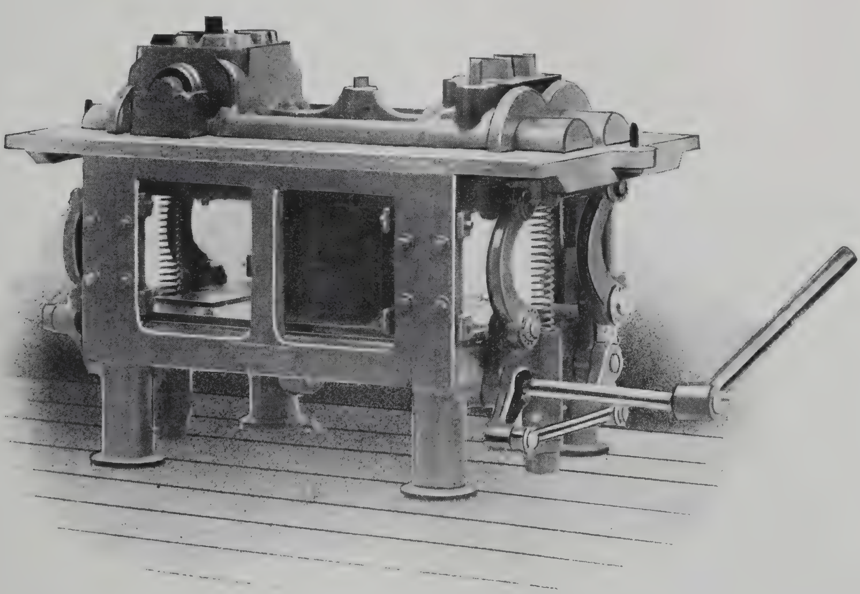


FIG. 6.—20 IN. BY 30 IN. HEAVY DOUBLE SHAFT MACHINE, MOUNTED WITH WOOD PATTERN OF "WORTHINGTON" STEAM PUMP.

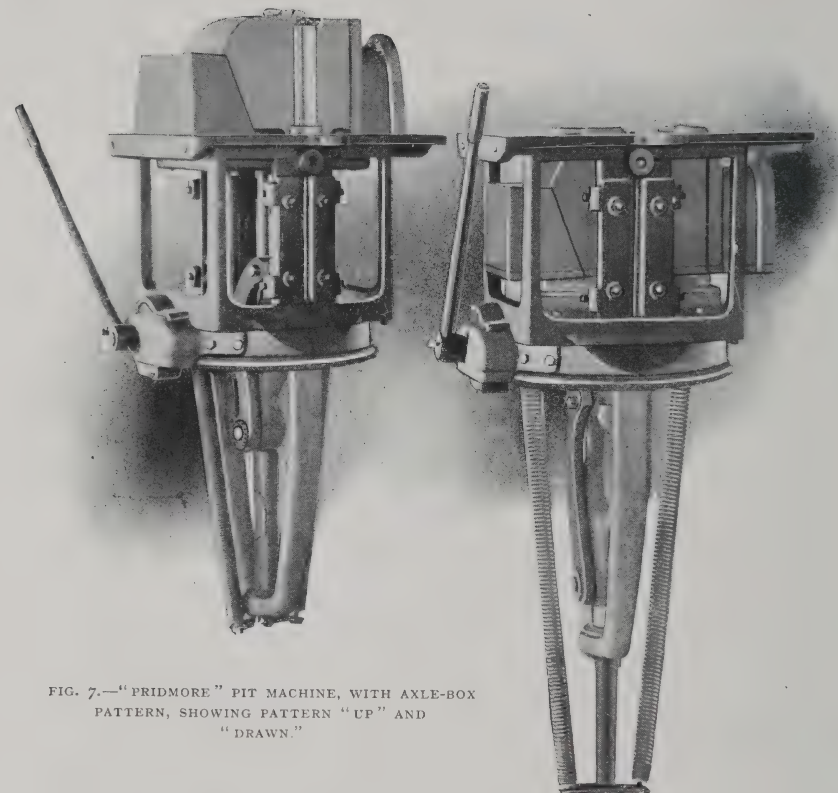


FIG. 7.—"PRIDMORE" PIT MACHINE, WITH AXLE-BOX PATTERN, SHOWING PATTERN "UP" AND "DRAWN."

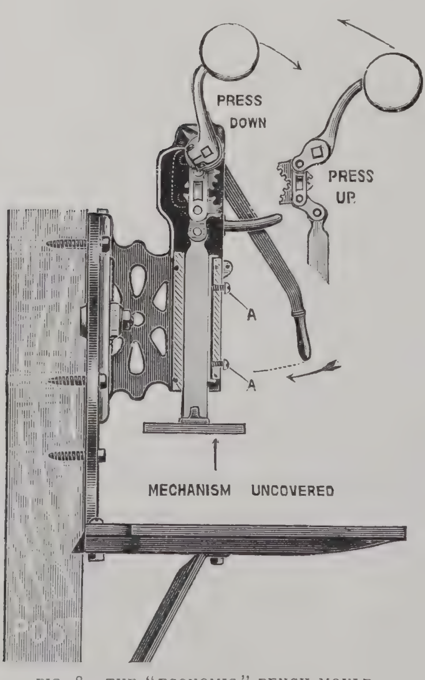


FIG. 8.—THE "ECONOMIC" BENCH MOULD, SECTIONAL VIEW

finished boxes are set down behind the machines, the machine being gradually moved down the floor as the space behind is filled with finished moulds, and the sand and empty boxes ranged along the floor are used. At the end of the day's work, the machines have travelled down the floor, and the boxes are all ready to be poured. By this method the men are always at their work, *i.e.*, filling sand and ramming, and there is no time lost in carrying empty boxes and sand to the machine and the moulds away from the machine, which in ordinary machine-moulding entails a considerable waste of time and energy.

The second type of machines (see Fig. 4) are designed for larger work than can be moulded in single stand machines, and are made in all sizes up to 120 in. long, but not wider than

20 in.; these machines have a maximum draw of $4\frac{1}{2}$ in.

For larger and heavier work another type of machine has been designed (see Figs. 5 and 6). These machines are made square in all sizes from 18 in. by 18 in. to 72 in. by 120 in., and round in all diameters from 18 in. to 72 in. They are made in three depths—for patterns requiring a maximum draw of 6 in., 8 in., or 10 in. This type of machine is used largely by such firms as the well-known steam pump makers, Henry R. Worthington, for large and intricate moulds, and give invariably good results.

previously been considered impossible for a moulding machine.

Outside the scope of the "Pridmore" machine there is a class of castings for which mechanical ramming is found perfectly satisfactory; such moulds are those requiring practically no draw to remove the pattern from the sand, and are chiefly made from half-round patterns such as are required for brass cocks and valves of small diameter, also moulds for malleable iron castings, or name plates and other small flat work. For this

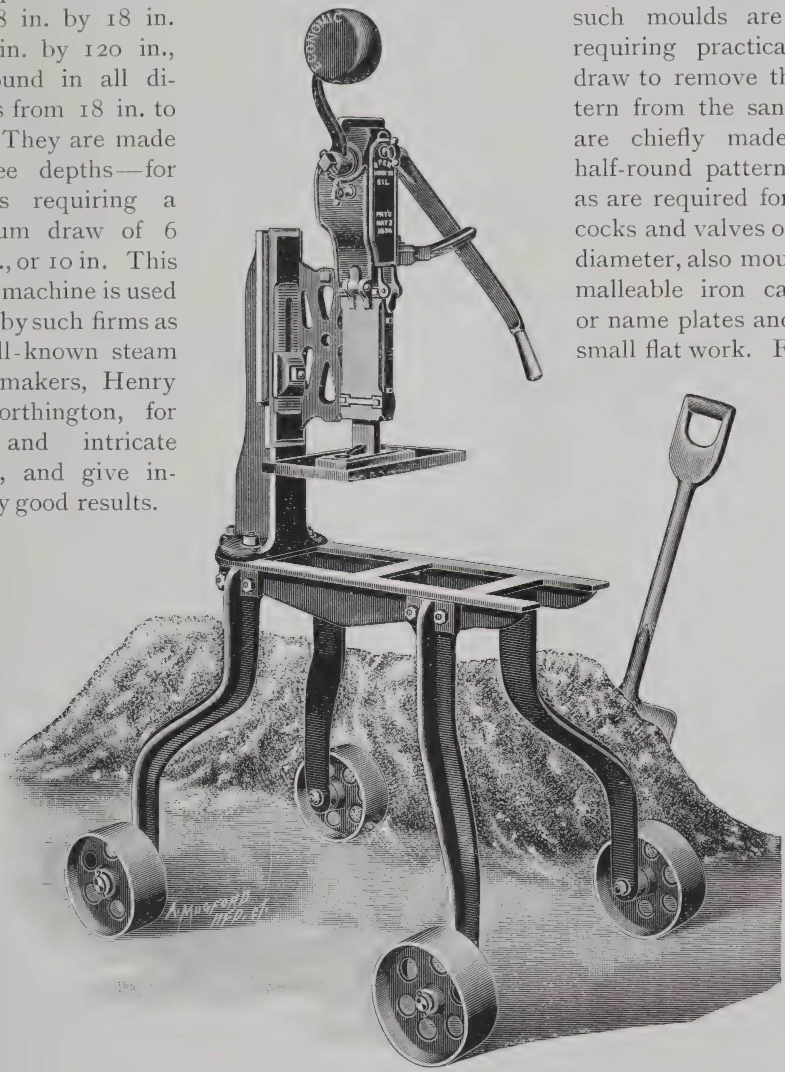


FIG. 9.—THE "ECONOMIC" MOVABLE MOULDING MACHINE.

Besides the above types, special machines are made for various purposes, such as axle boxes, where a specially deep draw is required (see Fig. 7), hangers, deep cored work, and several other classes of work which has

type of work mechanical ramming is perfectly sufficient, as the ramming head gives a perfectly even pressure over the shallow sand mould, and so leaves a good and sharp impression on the sand. Of machines of this class there are two

types, the pneumatic ramming machine, previously mentioned, and the simpler, cheaper machine illustrated in this article (Figs. 8 and 9), the working of which can easily be understood from the illustration. For bench or odd side work this machine, "the Economic," gives good results, and has been stated by the leading malleable iron foundries of the United States to save quite 40 per cent. over hand moulding for the same class of work.*

* For the light work to which this machine is suited, the best and most economical results are obtained by the use of wooden snap flasks or boxes.

There is not sufficient room in the limits of a short article to describe other foundry equipment and labour-saving devices which are largely used in America but are practically unknown here, but there are many other foundry "notions" in use there, such as air hoists, pneumatic sand sifters, casting cleaners, improved rumblers, etc., which are well worthy of the notice of English foundrymen who are desirous of increasing their output and producing good castings at the lowest possible cost.

J. W. Jackman.

LIFTING ELECTROMAGNETS.

By E. B. CLARK.

THE use of electrically energized lifting magnets on cranes, conveyors, and other hoists is a subject which has received far less attention than it deserves. Although whenever electromagnets are so employed in practice they have excited much interest, their use has not extended nearly so far as it could with much advantage. This fact, says the writer in the *American Electrician*, has been due to two reasons: (1) Mills and shops where bulky magnetic materials are handled have, until recently, not been thoroughly equipped with electric power. (2) Inasmuch as iron and steel products that are handled with power machinery are always heavy, large and powerful magnets must be employed, but there is practically no existing data dealing with the design and construction of such magnets that can be referred to in planning to build them.

In the early days of the study of magnetism, Sturgeon, Roberts, Joule and others succeeded in producing magnets of very considerable lifting power (from 2,000 to 3,000 pounds), but they were all excited by windings containing very few turns of comparatively large copper wire worked up to a very high temperature, and they were tested in laboratories under the most favourable circumstances. With such conditions they were enabled to get a high lifting power per pound of material in the magnet, but they did so at the sacrifice of certain other qualities that are all-important for magnets built for everyday rough use.

Magnets are valuable only where the material to be handled is magnetic, which practically means that it must be iron or steel, though there are special cases where other materials could be handled to advantage in iron receptacles. Another essential condition to make magnets especially useful is that the materia handled shall be bulky, and also awkward to pick up in any other way. With these existing conditions making magnets advisable it is still not possible to use them to advantage unless the material to be handled can present some readily accessible smooth surface to which the magnet face can be presented easily. These conditions frequently are all met with, most often in rolling mills, boiler shops and locomotive repair shops, but also in factories making other products, awkward to handle, as, for instance, projectiles. Generally it is inadvisable to try to handle with a magnet such irregular shapes as car wheels, castings, etc., and much of the existing prejudice against this mode of handling may be attributed to unsuccessful attempts to make such applications.

In rolling mills, where nearly all of the magnets now in use are employed, they are used to convey unsheared plates from the straightening rolls or the "hot-bed" to the shears, to convey the sheared plates from the shears to the inspecting beds, thence to remove them to the stock piles, or to load them on cars, as the case may be. Here a magnet is peculiarly fitted for its work.

A steel plate, especially as it comes from the rolls, is a decidedly awkward piece of material to take hold of. It is, perhaps, 40 ft. long, 8 ft. wide and $\frac{3}{8}$ in. thick. It is heavy, flexible and generally hot. If it is carried on roller tables, the tables must be long, for the plate must be cooled some and marked out before it goes to the shears, which means that there is a lot of machinery to keep in repair. If it is carried on overhead travelling conveyors, it must be picked up by several pairs of hooks, which must be attached by hand at the cost of much labour and time. If it is carried on travelling conveyors supporting it from below, two hot-beds must be provided to enable marking out, and a complicated lot of machinery installed.

If, however, it is carried by overhead conveyors, equipped with electromagnets, only one man is needed to operate the whole apparatus. He simply lowers the magnets down on the plate, turns on the current, hoists, runs his plate over to the desired position, and opens the switch. In handling long plates at the shears a crane equipped with an electromagnet on its hook can be of great assistance. In taking the sheared plates away, to be piled in stock piles or to be loaded in cars, cranes with magnets can save a great deal of time and enable the work to be done with much economy of labour that cannot otherwise be effected. This is proven by the fact that in those mills so equipped a disabled magnet will necessitate putting on two or three more men for each crane, and even then will cut down the speed of shipment by 15 per cent. to 30 per cent., according to the size and shape of plates.

The one great objection urged against magnets by those who are opposed to their use is that they are liable to drop plates or whatever they may be handling upon the heads of men passing underneath, either by reason of the current failing or because the plate is too near the capacity of the magnet to make it hold securely. It is argued that there is always a chance of the current being cut off unexpectedly, and that inasmuch as there is no way to tell absolutely whether a magnet will surely support a certain plate, there is always a chance of a large plate dropping off. Both of these contentions are, in the main, true, though by proper design of magnets and circuits the danger from both sources may be reduced to a minimum, but there is no need of handling plates in such a way as to endanger men's lives. Generally it is not necessary for men to get under plates at all, and in the few cases where it is, as for inspecting, guards may easily be arranged to protect against the remote possibility of a plate dropping. Besides, is it not a fact that men should keep from under bodies supported in any way on overhead carriers? Slings and hooks are just as liable to slip and break as are magnets to let go. As evidence on this point, it is perhaps worth while to say that during several years' experience with magnets used as above described, the writer has yet to know of the first accident caused by the unexpected dropping of a plate.

The amount of power consumed by an electromagnet, although generally so small as to be entirely unimportant, still is a point worthy of consideration. In every case it is almost altogether a question of design. Generally speaking, it may be said that the less a magnet weighs the less power will have to be expended per pound lifted. Also the less a magnet weighs the greater the ratio of lifting power to weight of magnet; in other words, the less the weight of the magnet the more each pound of it will lift. This follows from the fact that, roughly speaking, the lifting power of a magnet is a

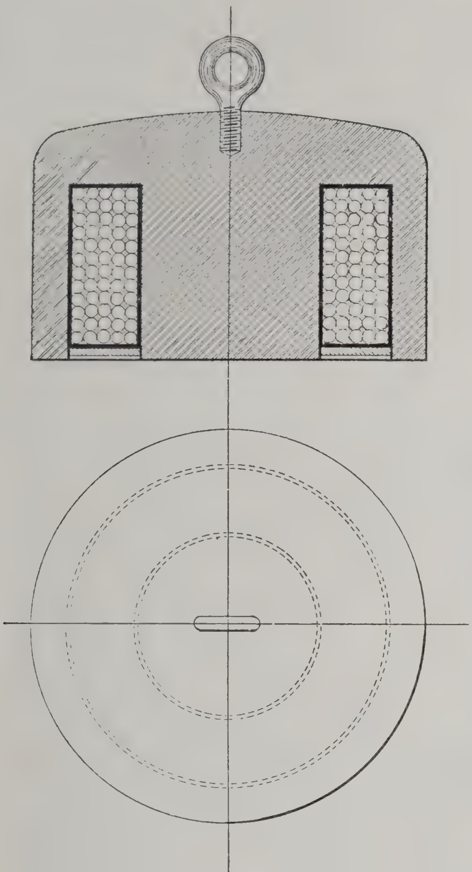


FIG. I.—LIFTING MAGNET.

function of the square of its linear dimensions, while its weight is a function of the cube of its linear dimensions. Therefore the ratio of its lifting power to its weight is the ratio of the square to the cube of its linear dimensions, a ratio that decreases rapidly with increase of size of the magnet.

It is, of course, true, with the design of magnets, as with the design of any other piece of apparatus, that the most desirable design is the one that, while it will do the work satisfactorily, can be built for the least money. And it is also true, here as elsewhere, that the cost of operation and maintenance is just as important a part of the designer's problem as is the first cost of construction. Both of these points are involved in a decision of the proper winding for the coils, which depends largely upon the service to which the magnet is to be adapted. The higher the current density the greater will be the heating effect and the consequent loss of energy and liability to burn out. On the other hand, the greater the current density the less copper need be used, which not only lessens the cost by reducing the amount of copper, but also by shortening the magnetic circuit, and thereby using power at a higher efficiency. It is by obtaining a happy medium between these two considerations that a successful design can be produced, and the location of this medial point depends, in any case, upon the character of the service which is expected of the magnet. The less constantly it is to be used, and the shorter is each period of use, the higher may the current density be run.

In general we may say that the calculation of a magnetic circuit may be proceeded with exactly as can the calculation of an electric circuit. That is,

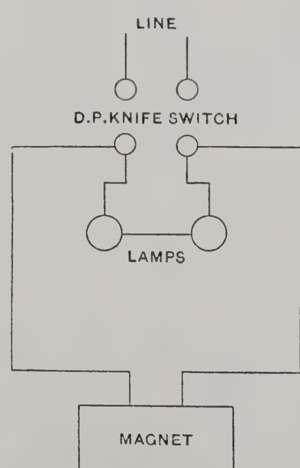


FIG. 2.—CIRCUIT CONNECTIONS.

given the amount of magnetism required, design the shortest (having least reluctance) magnetic path, which may be

encircled by a winding sufficiently strong to drive the required magnetic flux through the figured reluctance of the circuit.

It is a comparatively easy matter to arrive at the required amount of magnetic flux in any special case, because it is useless to run steel or wrought iron very much above the point at which the traction is about 150 lb. per square inch, though it is quite possible to get it up to a point where the traction will be 200 lb. per square inch if there is any special reason why such a point should be reached. But having determined upon the total number of magnetic lines and assumed a magnetic circuit, it is then not nearly so easy to estimate the reluctance of that circuit. Not only is the permeability of the materials rather an uncertain quantity, and the accuracy of the mechanical work of the joints in a certain measure indeterminate, but, far more important, the width of the air-gap between the pole-face and its keeper is exceedingly difficult of prediction. It is this air-gap, too, which forms the major part of the reluctance of the circuit. It will be found that if this is made large, say $\frac{1}{4}$ in., such an enormous magneto motive force will have to be employed to get a useful traction that the copper winding will be excessive. And yet in practice it would require a comparatively slight obstruction to hold the magnet $\frac{1}{4}$ in. away from the metal. It is this fact that makes the use of a magnet on any irregular shape difficult, for unless it is possible to lift the weight with far less magnetism than the maximum, an irregular shape cannot be picked up.

In arranging this magnetic circuit, the usual precautions against leakage must be observed, though other considerations governing the form of the magnet are so important as to make leakage a secondary point. It is a very difficult question to handle, and the limit of error is so great, owing to variable air-gap, that the only practical method of dealing with it is to use the least objectionable form and then to make liberal allowance for leakage. The form of the magnetic circuit has great influence upo its action and varies greatly with the work to be done. The magnet which will exert the greatest power in adhesion is the one having the shortest and most compact circuit, but this is not always the most desirable form for other reasons. In picking up plates from a pile it is sometimes desirable that only one shall be taken at a time, and sometimes preferable that a number shall be taken at once to expedite the work. Different forms of magnets are adapted to each case. It is frequently required to handle just one shape or one thickness of plate all the time, while in other cases a large range of sizes must be accommodated. A certain form is best adapted to each

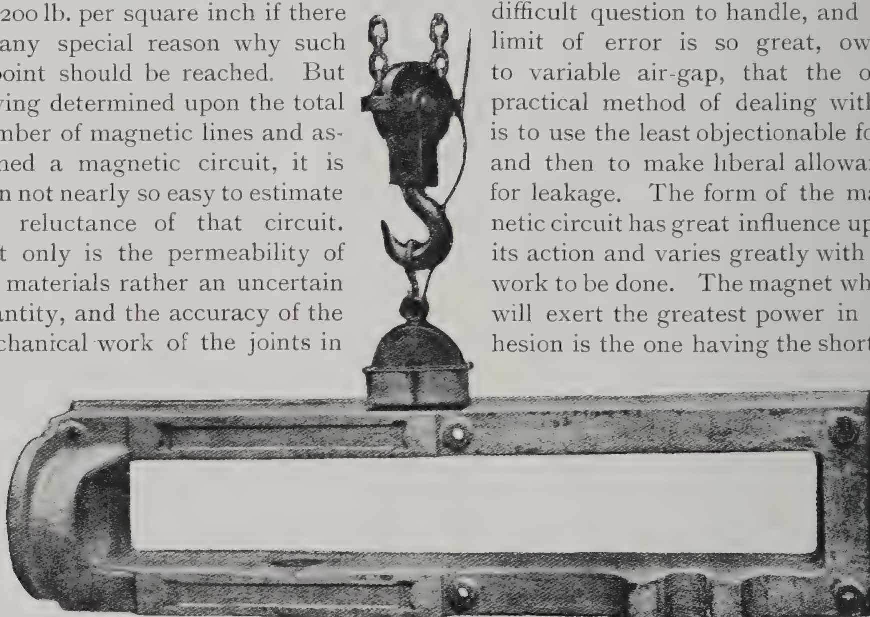


FIG. 3 —ELECTROMAGNET BY THE SANDYCROFT FOUNDRY CO., OF CHESTER, SHOWN LIFTING A CAST-IRON BED PLATE WEIGHING 2,000 LB.

class of work. But whatever the shape of the magnet, it must be mechanically substantial. The coils must be thoroughly protected from injury and must be provided with the best of insulation, for the magnet will receive hard usage. The points where the leads enter the case must be so protected as to admit of a broken lead being repaired easily, without taking the coils out. The whole magnet must be arranged to enable repairs to be made without trouble, for the work is rough and will damage any construction in time.

The form which upon first thought seems most suitable, both from a magnetic and from a mechanical standpoint, is a simple horseshoe with one limb developed to form an envelope for the rest of the magnet, as shown in Fig. 1. But further consideration and actual trial show this to be a poor form for such work as plate-handling, on account of the round shape of the pole-face and on account of the excessive leakage from pole to pole. A single large magnet is also undesirable, where a large area of effective surface must be provided, from the weight considerations previously pointed out. A group of small magnets of this general shape would be better, but the writer does not believe this form to be adapted to the work, notwithstanding the fact that it has long been a favourite shape and that some of the early inventions were based upon it.

The round pole-face does not offer sufficient resistance to the tendency of plates to bend and tear themselves away from the magnet. This tendency is the most serious one for the designer to combat in plate-handling, which is by far the most important use of magnets to date. A round magnet which will lift, on a straight pull, 10,000 lb. easily, will refuse to pick up a long thin plate weighing 1,000 lb. The magnet should present a straight line instead of the arc of a circle at the bend of the plate. For plate work a group of rectangular poles seems best in practice. Different dispositions of the same amount of material in a magnet produce surprisingly different results.

Frequently it is desired to regulate the strength of a magnet; that is, to cause it at times to pick up several objects, and at others fewer or onl one

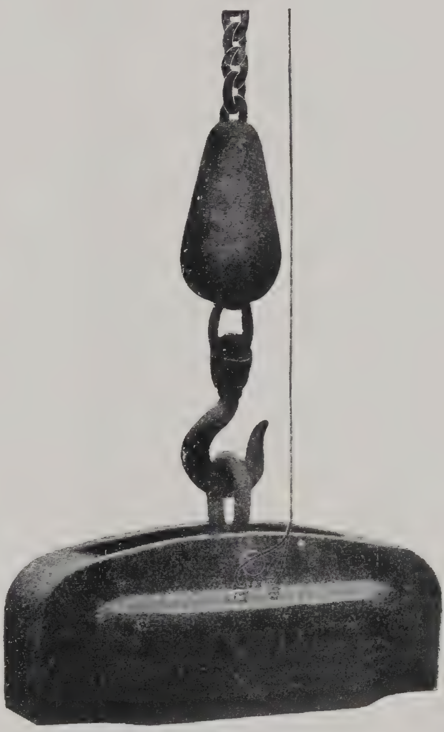


FIG. 4.—SHOWING SANDYCROFT STANDARD TYPE OF ELECTROMAGNET.

It is possible to do this by means of a rheostat in series with the winding, but such a means gives much trouble in adjusting and is apt to cause dropping. A better plan is have the operator drop off any superfluous material by opening the switch for an instant and quickly closing it again. As unlikely as it may appear, it is still nevertheless true that it is an easy matter for the operator in this way to regulate very easily and very simply exactly the load which he

wishes the magnet to carry, and then he can always have the maximum lifting power of the magnet available.

One trouble that may be met with is flashing, upon the opening of the switch, due to the natural kick produced by the opening of a circuit possessing high self-induction, and also to the current induced when gravity tears the keeper from the magnet face. The self-induction may be reduced by proper arrangement of coils, but it is best to adopt the following means of avoiding the evil influences of flashing at the switch, especially when several magnets are energized in multiple as when handling long plates. Connect a circuit of incandescent lamps or other non-inductive resistance in multiple with the magnet on the dead side of the switch, as shown in Fig. 2. The total normal voltage of the lamps should be about 50 per cent. more than the voltage across the line, and the normal current capacity of the lamp circuit about 50 per cent. of the current absorbed by the magnet. That is, if the magnet takes about 3 amperes at 240 volts, use 3 lamps each 50 candle-power at 120 volts.

By means of this precaution the puncturing of the insulation due to inductive action will be prevented. It is interesting to note the lamps gradually dim when the switch is opened and then, when the piece on the magnet finally drops, to see the lamps light up again for an instant as the induced current passes through them. Of course the lamps are placed at the switch near the operator when the magnet is in an unfavourable location. For regulating the strength of the magnet to provide for cases where an unusually large air-gap demands excessive magnetization to secure adequate lifting-power, the writer has found a series-parallel connection of coils to be a decided advantage.

If the magnet is suspended on a crane hook which travels through much vertical distance a reel must be arranged to coil up the lead wires and let them out again as the magnet moves up and down. Trolley wires must be provided to convey the current to the magnet.

The current consumption of a magnet depends upon the winding of the coils, but roughly speaking, a magnet for handling ordinary sheared plates, having a capacity of, say 3,000 lb., on this work should operate easily and satisfactorily on 1,000 watts. This same magnet under favourable conditions will lift 10,000 lb. with the same power consumption, but to do this the keeper must be accurately fitted to the pole faces.

NEW RECORDING AIR PYROMETER.*

By WILLIAM H. BRISTOL.

THE instrument herein described has been designed to meet a demand for a pyrometer to measure temperatures of high ranges, and to give continuous records of changes of such temperatures on a moving chart; also to produce an instrument which would be self-compensating for barometric and thermometric changes of the atmosphere without introducing delicate mechanism, which would tend to inaccuracy and to preclude its use for commercial purposes.

The diagram (Fig. 1) shows the arrangement of the parts of the pyrometer, which consist simply of a porcelain bulb connected by a capillary tube to a recording pressure gauge. The stem of the porcelain bulb is made of sufficient length to pass through the furnace wall. The capillary connecting tube is made of seamless copper. The recording pressure gauge employed is constructed on the same plan as those previously described. By reference to the description, it will be found that each pressure tube or spring is constructed on the Bourdon principle, and consists of a tube of closely-flattened cross-section formed into a helix of two complete turns.

Two of these pressure tubes or springs are employed in the recorder—one of these, the indicating tube or spring, being connected to the air bulb by the capillary tube, and adapted to be turned axially by the variations of pressure due to changes of the temperature to be measured; the other, a compensating spring, is mechanically attached to the free end of the indicating tube or spring.

The compensating spring is adapted to be turned axially by variations of atmospheric pressure and temperature in a direction opposite to the motion of the first or indicating spring under the same influences.

Fig. 2 shows an interior view of the recording portion of the instrument. The compensating and pressure tubes are lettered respectively A and B. These tubes are made of equal strength, hence external or internal pressure will produce the same angular movement in each.

The air bulb, capillary connecting tube, and indicating spring are almost exhausted of air, so that when the air bulb is cold it is subjected on the exterior to nearly atmospheric pressure; but when the bulb is exposed to high temperatures, the remaining inclosed air is expanded so as to practically balance the external pressure, and the bulb is relieved of strains which would, in its weakened condition, tend to injure it.

Fig. 3 shows the indicating and compensating springs of the recorder on an enlarged scale. C is the bracket to which one end of the indicating spring B is secured; D represents a portion of the capillary connecting tube where it enters the stationary end of the indicating spring. The compensating spring A is helically formed in the same direction as the indicating spring, but of a larger diameter, so that it may be placed

* Presented at the December meeting of the American Society of Mechanical Engineers.

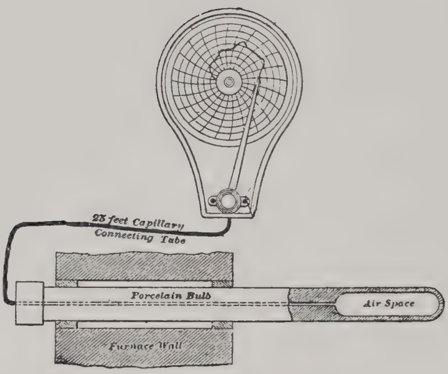


FIG. 1.—RECORDING PYROMETER.

outside of and concentric with the indicating spring, as shown, and is mechanically attached at E, there being no opening or connection between the interiors of the two springs. At the free end of the compensating spring a bracket F is soldered, making a rigid connection to a shaft through the centre of the springs. At the front end of the shaft the recording arm G is rigidly secured.

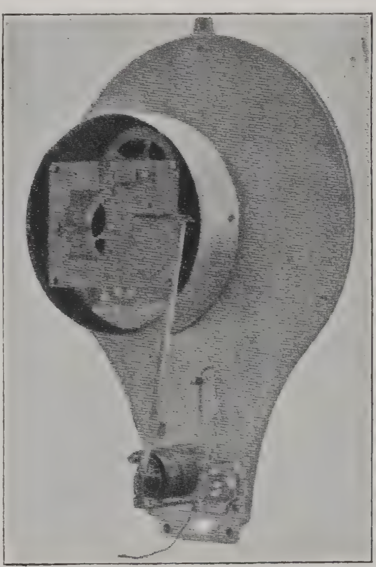


FIG. 2.—INTERIOR VIEW.

To illustrate the operation of the compensating spring, assume that the air has been partially exhausted from it, and that the barometer rises under such a condition: the indicating spring would turn to the left (Fig. 3), if the compensating spring was not present; that is, in direction of arrow 1; but the compensating spring A being present, and tending to turn to the right, as indicated by arrow 2, through the same angle, the effect of changes in atmospheric pressure is neutralized, and the position of the recording arm is unaffected by the rise of atmospheric pressure. For the same reasons there would be no movement of the recording arm when there is a fall in atmospheric pressure.

If the air is not entirely exhausted from the compensating spring, it will also compensate for thermometric changes in the same manner, the indicating spring tending to turn in the direction of arrow 1 when the temperature falls, and in the direction of arrow 2 when it rises; while the compensating tube will be turned in opposite directions equal amounts under the same influences. By leaving the proper amount of air in the compensating spring, the compensation may be made perfect for any change of atmospheric temperature, provided the air bulb is at a given temperature. The error for small variations from the average temperature to be measured will be so small that it may be neglected. As the tubes are turned in opposite directions by barometric and thermometric changes, it is evident that there will be no movement of the recording arm unless due to changes of pressure communicated to the indicating spring through the capillary tube from the air bulb exposed to the temperature to be measured.

The helically formed pressure springs

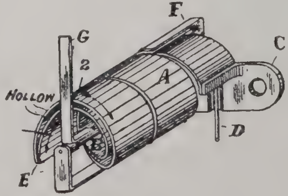


FIG. 3.—INDICATING AND COMPENSATING SPRINGS.

are particularly well adapted for use in this instrument, on account of the small internal space, which, together with that of the capillary connecting tube, forms a small volume in comparison with that of the air bulb.

Thus far special attention has been given to working out the mechanical features of the instrument, and to determine experimentally on the most practical form of the porcelain air bulb, and how these bulbs may be applied to continuously record high temperatures. As the volume of air space outside of that exposed to the temperature to be measured is very small, and as there are no corrections or computations necessary for barometric or thermometric changes, it will be a simple matter to calibrate the instrument according to the theory of the air thermometer, which is a recognized standard for measuring temperatures. The instrument here exhibited has been calibrated by comparison with a standard from 32° up to 600° Fahr., and by the melting points of aluminium and copper for the scale up to 2,000° Fahr. This instrument is the joint invention of E. H. Bristol and the author.

NEW MACHINERY, APPLIANCES, ETC.

(Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.

WORTHINGTON COOLING TOWERS.

WE illustrate two cooling towers, recently erected by the Worthington Pumping Engine Company at Stuttgart.

These towers are of the natural draught type, and are each capable of cooling the condensing water for condensing 22,000 lb. of steam per hour. They are each 14 ft. in diameter and 82 ft. high, and the cooling surface consists of a number of layers of interlocked galvanised steel pipes, so placed to give perfect intermingling of the falling water and the rising air in the tower.

The towers are erected on concrete foundations with concrete piers, so built as to allow ample area for the air passing through the cooling surface. The cooled water falls into a well constructed in the concrete foundations. The cooled water wells of the towers are connected up by means of a culvert.

The hot water discharged from the towers rises directly between the towers, with branches to each, and are so arranged that either tower can be cut out when necessary. The distribution of this water is effected by means of a distributor, which revolves on a central bearing, the general arrangement of this being similar to a Barker's mill.

The advantage claimed in the adoption of a tower of this class over the forced draught tower is, of course, the saving in first cost of the fan and motor, and the continuous saving in power, which economies soon repay the extra cost of the cooling tower shell.

ELECTRIC FURNACES.

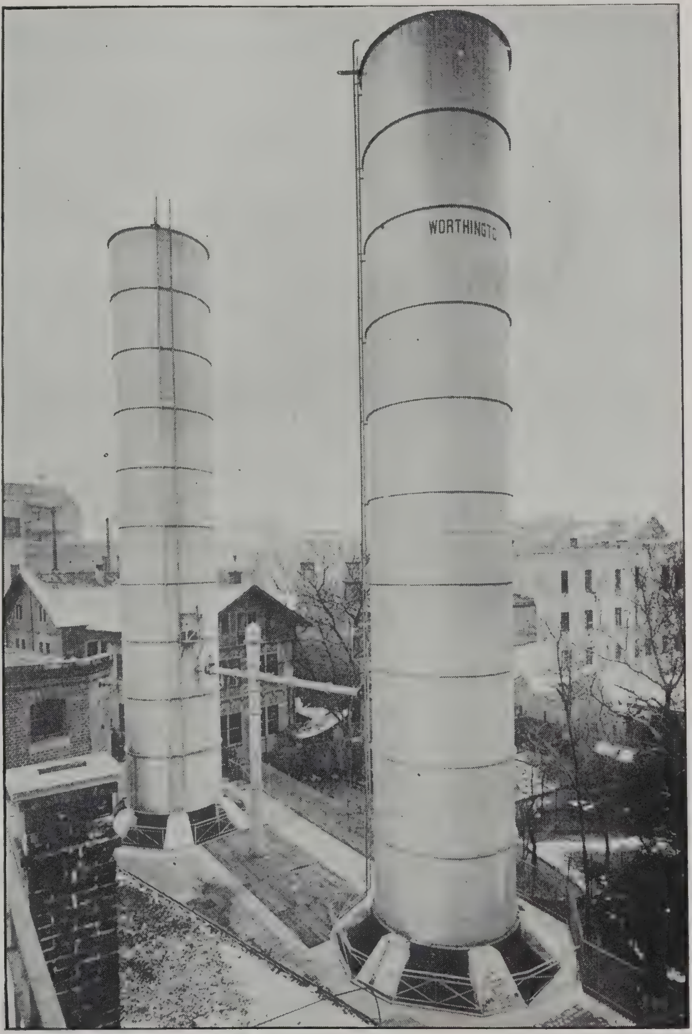
THE HATCH FURNACE.

THE general principle of the Hatch smelting furnace is that of putting the raw ore in a closed cylinder, with carbon bars heated by the current arranged around the lining of the cylinder, the cylinder being revolved and the carbon bars being cut in and out of circuit as the cylinder revolves, so that no current passes through the ore. Fig. 1 shows the furnace open with one end removed, and Fig. 2 shows the furnace with the end bolted on, but with the hole in the centre open for charging and for the escape of gases while roasting preliminary to smelting. As can be seen in Fig. 1, the interior of the furnace has seven sets of carbon bars, each set of bars forming one side of a polygon, there being ten bars in each set. The ten bars in each set are electrically and mechanically in parallel, and each set is electrically independent of the other sets. Only one set of carbon bars is connected in circuit at one time. The furnace is revolved on the rollers, shown in both engravings, at the rate of one revolution every two minutes.

The furnace is filled about one-third full of ore, and is revolved in the direction of the hands of a clock. Projecting

radially from the casing of the furnace are seven pairs of switch blades. Each pair is connected to the set of carbon bars nearest to it inside the furnace. As the furnace revolves clockwise, the set of carbon bars which are in the position marked L in Fig. 1, are made live by the contact of the switch jaws of its set with the heavy stationary brushes mounted on the pillar at the right. As soon as the furnace revolves far enough, so that the section just mentioned is cut out, the next section above it is cut in and so on —one section always being in circuit. A current is passed sufficient to bring the carbon up to a white heat. The objects of such a rotary arrangement of furnace are several. By the revolution of the drum the heat is more evenly distributed to the ore, and overheating and volatilization of some portions of the ore has been avoided; the passage of current through the ore itself is obviated, and by doing this a great deal of uncertainty is avoided as to the degree of heat; the ore is constantly being stirred, so that the action is more even on the mass.

Many failures in electric-furnace work, as well as poor results in ordinary smelting of lead and zinc ores, are due to inability to control the heat, and to the overheating of some parts of the mass without sufficient heat in the other parts. The present furnace has been successfully tried, Mr. Hatch says, on refractory lead and zinc ores, which require an exact regulation of the degree of heat, because the metals volatilize at a very low temperature, and overheating causes a loss of metal. In the furnace illustrated the carbons are 1 by 2 in. in



TWO WORTHINGTON COOLING TOWERS ERECTED AT STUTTGART.

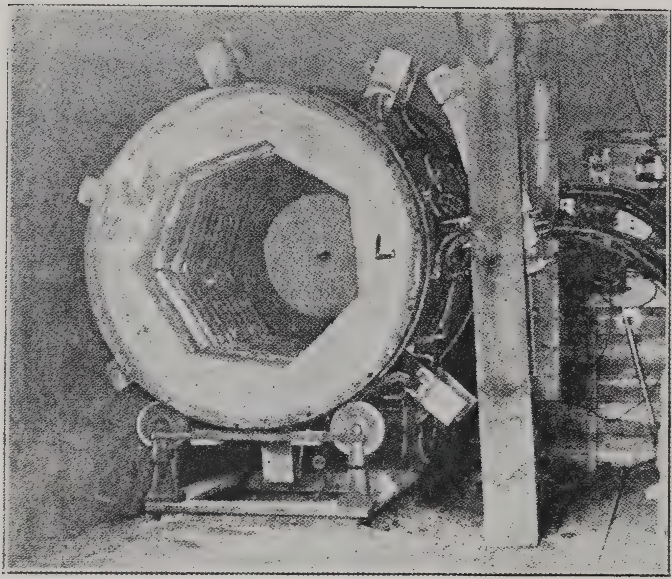


FIG. 1.—THE "HATCH" ELECTRIC FURNACE, SHOWN WITH ONE END REMOVED.

section, and contact is made with them by 1-in. copper bolts. They rest on the fire-brick lining of the furnace, and are spaced 2 in. apart, so that the ore falls down between them as well as on top of them, and has good opportunity to absorb heat. Channels are provided under the carbons, in the firebrick lining, for the smelted ore to run into, and from these it is drained occasionally. The case of the furnace is of boiler iron. The furnace is 4 ft. outside diameter and 3 ft. inside diameter; 5 ft. long outside and 4 ft. long inside. The current taken is 600 amperes at 10 volts, or 60 kilowatts. The furnace will smelt 3 tons in 3 hours—2 hours being taken to roast the ore and 1 hour to smelt it. The roasting is done at a temperature of about 1,000° F. on refractory Galena lead ore tested, and it is then raised to 1,500° F. to smelt. With energy at ½*d.* per kilowatt-hour, Mr. Hatch figures that the cost per ton for smelting is 6*s.*, against 24*s.* to 32*s.* for smelting direct with coke in the ordinary way.

DUCASSE FURNACE.

The furnace is circular in plan, with a movable hearth, the whole of which acts as the negative electrode. A tap hole is provided to run off liquid smelting products, and in the upper portion of the furnace is a side flue, provided with a sight hole and cleansing door; through this flue the heated furnace gases are carried to a chamber, in which the furnace charge is perheated. The furnace is surmounted with a dome cover fitted with an eye-bolt, by which it may be raised from its position, and perforated with charging doors and with four apertures, through each of which passes one of four carbon rods, forming the positive electrodes. These electrodes are supported from

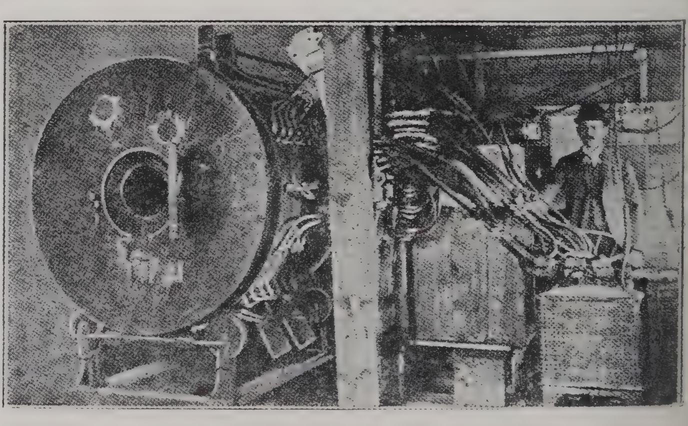


FIG. 2.—THE "HATCH" FURNACE, SHOWN WITH THE END BOLTED ON

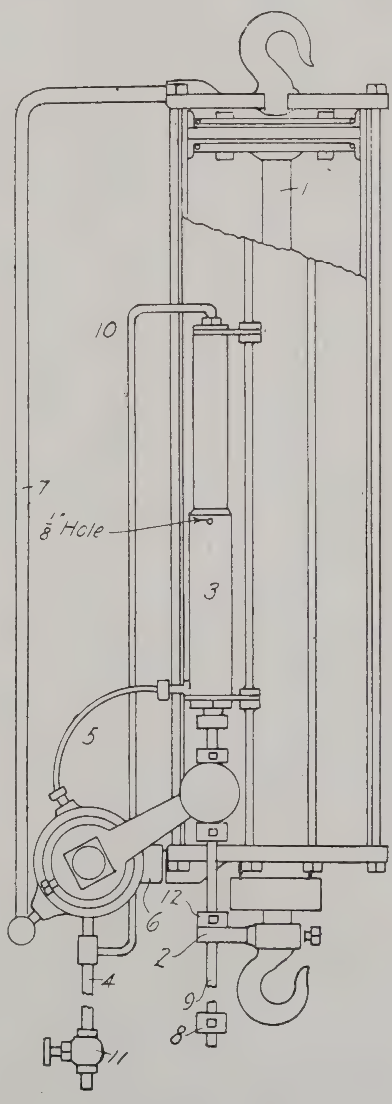
above in such a way that their position may be regulated automatically or at will. By means of a motor working on a shunt from the main circuit, a rotary current - distributor causes the main current to pass through each of the electrodes in succession 3,000 times a minute, contact with any one carbon not being broken until that with the next has been made, so that sparking is avoided. There is in this way produced in the hearth of the furnace an arc which practically rotates at 3,000 revolutions a minute.

A NEW AUTOMATIC FIRE ALARM.

A VERY novel and efficient fire alarm has been patented by Clar & Co., of Runscheid, Germany, and is being introduced into this country with every success by Mr. H. B. Richardson, 143, Cannon Street, London, E.C., who has procured the sole rights of the patent for the United Kingdom, and where the alarm can be demonstrated, as it will be fitted in practice. The chief features of this alarm are its simplicity, efficiency, and its capability of not only being of service in a mere portion of a room or structure, but it is in evidence throughout the whole of the room, and no matter where a fire should occur, its presence, by adoption of this alarm, is told instantaneously and automatically. Specially adapted contact boxes are placed in the walls of rooms, the points of contact in these boxes being kept apart by patent impregnated cord, which is led around the walls towards the ceiling. This cord is so contrived that not only will it break by direct flame, but that a high temperature alone will sever it. When severance takes place, tension is released, and the points of contact in the contact boxes come together. These being electrically connected with alarm bells, placed in such portions of the building as may be desired, a current is formed, and the presence of fire at once and automatically notified.

A NEW PNEUMATIC HOIST.

A NEW type of pneumatic hoist has been successfully introduced by an American engineer to do the "jumping" or "stoving up" of heavy pieces like engine draw-bars, etc., in blacksmiths' shops. The chief feature



A NEW PNEUMATIC HOIST.

is the application of a special valve arrangement, which we illustrate.

An air lift cylinder with a 6 in. piston and 4 ft. stroke is supplied with piston of the double leather type, and a tappet arm 2. The auxiliary cylinder 3 is of the differential type. The multiple way valve 4 is so ported as to allow pressure to pass through small pipe 5, to the large end of the auxiliary cylinder 3 just before the piston reaches the full upward stroke, moving the handle on valve 4 to position as shown. This opens a $1\frac{1}{4}$ in. exhaust port and allows pressure to escape through the connection 6, and the centre of the valve 4, while pressure is simultaneously admitted through pipe 7 to top of the cylinder to force the piston 1 down until the tappet arm 2 reaches the tappet 8, carrying piston rod 9 of auxiliary cylinder 3 down until the port in valve 6, communicating with large end of auxiliary cylinder 3, is opened. This allows the pressure to escape through pipe 5 and the centre of valve 4, when the constant pressure admitted to small end of auxiliary cylinder through the pipe 10 will move the piston in auxiliary cylinder 3 down. This carries the handle of the valve (which is provided with a jaw to fit loose over the piston 9 and between the two tappets) to a position which registers the port to receive air through pipe 6 and exhaust from top of main cylinder through pipe 7 and the centre of valve 4.

In operation, the piece to be shortened is heated and hung on the lower hook, while piston 1 is clear down, with a chain that can be easily adjusted with slack enough to allow for shortening, the bar resting on the iron block or anvil. On opening the valve to pipe 11 connecting with the air pressure supply, the piston rod 1 will travel up until the tappet arm 2 reaches the tappet 12, and moves the handle on valve 4 until pressure is admitted through pipe 5 to auxiliary cylinder 3. The piston being of greater diameter here than the one on top, it will force the handle to full port opening, as shown for the exhaust through pipe 6 and valve 4. Simultaneously the pressure is admitted through pipe 7 to top of main cylinder, forcing the piston and rod 1 down until the tappet arm 2 reaches tappet 8, which carries the piston rod 9 with it until the exhaust port in valve 4, that communicates with auxiliary cylinder 3 through pipe 5, will be opened just before the main ports in valve 4 open. The pressure is then allowed to escape from the large end of the auxiliary cylinder 3, and with the constant pressure on the small end of the piston through the pipe 10, it will move the handle to valve 4 to the opposite position as shown, when the operation is repeated.

REVIEWS.

Manual of Electrical Undertakings 1900–1901.

By Emile Garcke, M.I.E.E., etc. London: Donington House, Norfolk Street, W.C. 12*s*. 6*d*. nett.

This is the fifth annual volume of this manual, the value of which increases with each issue. It numbered in Volume IV. 1036 pages, while the present one numbers 1272. This increase is a good indication of the year's growth in electrical enterprise, for the present volume deals with 117 more undertakings than its predecessor. By employing a thinner paper, however, the size of the volume has been reduced, which adds to its value for easy reference. The information is again classified under Telegraph,

Telephone, Electricity Supply, Electric Traction, Electrical Manufacturing, and Miscellaneous Electrical Undertakings. Each of these sections is preceded by some general notes and figures applicable to the particular branch of the industry. There are also, arranged alphabetically, a Directory of Officials, and Lists of Electrical Companies registered since 1856, giving the year of registration and the amount of capital. These lists, together with the particulars appearing under the above-mentioned sections, afford a record of all electrical companies formed under the Joint Stock Acts, and of all electrical undertakings belonging to local authorities.

The work also contains a map showing the Electric Railways of London, constructed and authorised.

There are also historical notes of interest and importance on electrical undertakings. No one interested in electrical affairs can afford to be without this annual.

Sewage Disposal Schemes:

Local Government Board Requirements. Tabulated by S. H. Adams, of York. Price 2*s*. 6*d*.

This is got up in the shape of a chart, showing, as its title signifies, the Local Government Board requirements relating to sewage disposal schemes. Copies should be in the hands of all sanitary engineers and surveyors.

The "Practical Engineer" Pocket-Book, 1901.

Manchester: The Technical Publishing Co., Ltd. Price 1*s*. and 1*s*. 6*d*. nett.

This is the twelfth issue of this Pocket-Book, which engineers have now come to look upon as quite an old and trusty friend. We find that many additional tables have been included, and some sections rewritten. Two additions which have increased the value of the book are the recommendations of the Institution of Civil Engineers upon the best standard of efficiency for steam engines, and a table of multipliers for finding the initial mean or terminal pressures of steam with any given cut-off up to $\frac{1}{20}$th stroke. We again recommend it to our readers.

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The "Practical Engineer" Electrical Pocket-Book, 1901.

Manchester: The Technical Publishing Co., Ltd. Price 1*s*. and 1*s*. 6*d*. nett.

We have before us the second issue of this book, which we find has grown from 256 to 292 pages. The same care in compilation is evinced here as in the older publication to which we have just referred. Sections have been revised and valuable additions have been made, not the least important amongst which is a table to facilitate the proportioning of resistance frames.

AN HOUR AT THE PATENT OFFICE.

Selections from recently published Patent specifications. Complete copies may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, E.C. Price 8d. each.)

No. 23,545. "Mills or Apparatus for Grinding and Polishing," W. O. Bailey, of The Excelsior Works, Wenlock Road, City Road, London. Dated November 25th, 1899.

The grinding ring is formed with a corrugated ratchet-shaped or other irregularly-shaped internal edge, such corrugations or the like extending a suitable distance into the grinding face of the ring. The irregular edge takes up the medium effectually, and also serves to distribute the medium equally in

between the grinding face and the surface to be ground, the centrifugal forces causing the medium to gradually travel to the outer edge or periphery of the ring.

* * *

No. 24,117. "Power Hammers," H. Guyot, of La Soutterraine, Department of Creuse, France. Dated December 4th, 1899.

Two hammers are provided, and each may be operated separately by belt gearing or simultaneously by the combination of the belt gearing with a special engaging device in which the shaft consists of two portions adapted to be rendered rigid one with the other by means of a key.

* * *

No. 25,016. "Means for Cooling Motor Cylinders," R. W. Barker, of Vulcan House, 56, Ludgate Hill, London. Dated December 16th, 1899.

A continuous spiral fillet is provided on the external surface of the cylinder, the said fillet being similar to a screw thread, the pitch of which is very fine, and the depth or thread being rather deep. A series of wide thin circular metallic pieces are screwed on to the fillets, and closely fit the same, and form wings for the purpose of cooling the metal of the cylinder.

* * *

No. 25,717. "Machines for Punching or Stamping Metal," The David Kimberley & Sons' Tool Manufacturing Co., Limited, and W. Kimberley, all of Highgate Tool Works, Emily Street, Birmingham. Dated December 30th, 1899.

A base or foundation of iron or steel is provided, having a tail-piece screwed at its lower portion for affixing to a bench, and with a square for use in a vice. Two levers of equal size are provided with a triangular or other projection at about three-quarters their length, and one lever or rocking bar with the projection quite at the end. This latter rocking bar or lever is pivoted at one end to the base with its longer portion in the same line as the base or foundation; a handle is provided at the opposite end to the pivoted portion, and by means of two rigid links the handle and the longer end of the rocking bar are connected by pivots. The two duplicate levers are pivoted at the projecting parts, and the ends of the levers at the longer ends are in turn pivoted, the lower one to the base and the higher one to the small rocking bar first described. At the end of the shortest or outward end of the duplicate levers holes are bored, the upper one to receive a stamp or punch, and the lower one to allow the passage of the piece of material punched from whatever the machine is used upon. The handle being depressed pulls down the vertical links, which draw with them the outer end of the small rocking lever bar first described, thus tilting up the nearer end of the top duplicate lever and tilting down the nearer end of the bottom duplicate lever, thus bringing down the punch on to the material to be punched.

* * *

No. 21,740 of 1899. J. Crabtree, of Lincoln, for "Appliance for attaching and detaching a chain coupling between railway waggons."

The appliance consists of a main shaft or bar mounted to slide and rotate in links fixed at the ends of the waggons and of arms on the bar engaging with the end coupling link. By rotating the bar the end coupling link is raised and then the bar can be swung forwards or backwards by means of the links to pass the end coupling link over the hook. The coupling link can be brought exactly opposite the hook by sliding the bar sideways in the links. The bar is provided with handles or levers at each end which are so placed as to be at or near the outside of the buffers of the waggon where they can be conveniently got at.

H.M. TORPEDO BOAT DESTROYER "ALBATROSS."

Built by Messrs. John I. Thornycroft & Co., Chiswick. Length, 227 feet ; Beam, 21 feet 3 inches ; Draft, 8 feet 5 inches ; Speed, 32 knots.

The Engineering Times.

Vol. V. MARCH, 1901. No. 3.

The Present Position of Underground Electric Railroads.

Engineers have, of late, been eagerly on the look-out for information regarding the twin tunnel electric underground lines of London. The three which are already in operation are clearly furnishing those concerned with the construction and equipment of new and similar railways, with most valuable object lessons. An examination of the systems of the Waterloo and City, the City and South London, and the Central London Railways brings home to one's mind the fact that in the construction, electrical equipment, and working of these three lines there are to be found many things which will not be found in later undertakings of their kind. It does not appear, as yet, to have been definitely decided as to whether the tunnels should be "close-fitting," or whether they shall be of much larger diameter; nor is there anything approaching to certainty in regard to the system of electrical working, whether locomotives of light construction, as on the South London, or heavy ones, as on the Central London, are the right thing; and, again, whether multiple unit methods, of which there are several available, are, or are not, capable of providing a satisfactory solution of the whole problem. The smaller, close-fitting tube principle is being avoided on the Great Northern and City Line now in course of construction, and the tunnels will be of a greatly larger diameter (16 ft.). The objects of this divergence from ideas laid down over ten years ago and closely followed until now, are to improve the air circulation and ventilation, at the same time reducing the resistance to the train, with a resultant power economy. Further, the larger tunnels will admit of space being allowed by the side of the train, so that with side doors passengers need not remain long in jeopardy in the event of stoppages, from any cause whatsoever, in the tunnels. Yet, again, a further advantage of the larger tunnel is that it admits of the largest rolling stock manufactured to be taken advantage of if desirable. These satisfactory features are not to be obtained without a heavier capital expenditure than on the "tube" lines, and in some quarters there exists scepticism as to whether the business to be done will give a good return upon the outlay. One other point of difference between this and previous lines is to be found in the substitution of brickwork in cement for the lower half of the tunnels. Sir Charles Scotter recently explained that the tunnels are made and lined with iron, and after the line is completed and the tunnel is projected forward, the lower half of the iron shields are taken out and brindle bricks in cement substituted; so that the lower half of the tunnel is ironwork, and the upper half

iron segment. It is considered that with this method of construction all possibilities of vibration will be reduced to a minimum. When the Great Northern and City Railway first came before the public, it was intended to employ electric locomotives; but railway authorities and others seem to regard the heavy locomotives of the Central London as being at the bottom of the vibration troubles. Evidently falling into line with this view, the board of the Great Northern and City now appears to be quite open to adopt "multiple unit" traction, with the motors distributed throughout the length of the train, on the different carriages. One must not overlook the fact that to the City and South London Railway belongs much credit for the very valuable pioneering work which it has accomplished. It is interesting to learn that since this railway started running, now nearly eleven years ago, not a single complaint as to vibration has been made by residents in the streets above. In Mr. Mott's opinion, the reason lies in the lightness of the locomotives and rolling stock. It seems that the entire weight of a City and South London train is not so great as that of the locomotive alone on the Central London. Certain points in the Central London permanent - way are also regarded as contributory causes of the vibratory troubles; but as the Board of Trade Committee will shortly conclude its investigation of the matter, we shall doubtless know the real facts of the case before long. The general opinion is that the complaints of vibration effects are grossly exaggerated.

It is not within our province to consider the financial positions of these railways, but it is satisfactory to find them all paying dividends, although as yet they are small. The working expenses, however, are interesting. Fuel and materials are of course very high in price, and have affected this item. The Central London working expenses are now figuring at $58\frac{3}{4}$ per cent. of the receipts; the Waterloo and City are below 55 per cent.; and the City and South London are $56\frac{1}{4}$ per cent. If from the last figure the cost of working the lifts was deducted, the cost of working the railway would be only 48 to 49 per cent.

That these electric underground railways are meeting a long experienced need is very evident from the large traffic which they are carrying from day to day. The Central London is carrying something like thirty millions of passengers per annum, the Waterloo and City about four or five millions, and the City and South London considerably more than ten millions.

• • •

The New Proposed Compass Card.

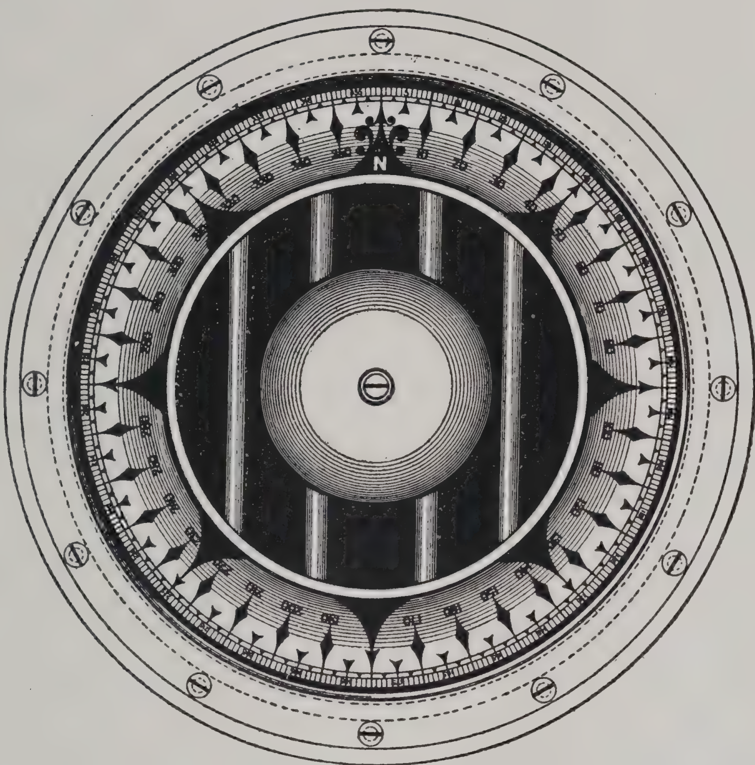
We are enabled to give a reproduction of the new design for Compass Card proposed by the Hydrographic Office of the United States. It will be seen that the card is graduated in a circle of degrees continuously to the right from 0° to 360°, omitting the present system of points. The designer's explanation of it (which we take from "The Marine Review") is as follows:—

The circumference of the card is divided into the usual 360 degrees and marked continuously to the right, from 0° at north to 90° at east, 180° at south, 270° at west, and 360° at north. The card is subdivided as follows:

(*a.*) Into divisions of 10 degrees, accentuated by heavy lines on the graduated rim, and by suitable geometric figures on the card, each 10-degree division of the card being indicated in figures by its appropriate number from 0° or north.

(*b.*) Each 10-degree division of the card is further subdivided into half

and quarter divisions, and appropriately marked.



NEW DESIGN FOR COMPASS CARD PROPOSED BY THE HYDROGRAPHIC OFFICE OF THE UNITED STATES.

(*c*.) Every fifth-degree line of the graduated circle between the 10-degree divisions is marked in figures, indicating its appropriate number from 0° or north.

(*d*.) The cardinal and intercardinal directions are emphasised on the card in geometric figures.

The object of the proposed change is to omit the present system of points and fractions thereof, and use degrees only. The present card contains points and degrees. The conversion of one into the other is a natural result of the presence of both, but is not a necessity, as would speedily be recognised were the points omitted. Accuracy requires expression in degrees for courses, bearings, and compass errors, and not in points, the use of which is but a duplication of work. A comparison of a few leading features of the present system with that proposed is given below:

PRESENT CARD.

360° = 32 points.
1 point = 11·25°.
$\frac{1}{2}$ point = 5·625°.
$\frac{1}{4}$ point = 2·8125°.

Graduated circle is marked in degrees in each quadrant, from 0° at north and south, to 90° at east and west.

The fifth point is N.E. by E., or N. 56° $\frac{1}{4}$ E.

The thirteenth point is S.E. by S., or S. 33° $\frac{3}{4}$ E.

The course is S. 18° E., or S. by E. $\frac{5}{8}$ E.

Easterly deviation is additive in the N.E. and S.W. quadrants; subtractive in the S.E. and N.W. quadrants, to compass course to get magnetic.

Westerly deviation is subtractive in N.E. and S.W. quadrants; additive in S.E. and N.W. quadrants, to compass course to get magnetic.

PROPOSED CARD.

360° = 36 divisions.
1 division = 10°.
½ division = 5°.
¼ division = 2·5°.

Graduated circle is marked in degrees continuously to the right from 0° at north to 360° at north again.

The fifth division is 50°, a multiple of 10°.

The thirteenth division is 130°, a multiple of 10°.

The course is 162°.

Easterly deviation is always additive to compass course to get magnetic.

Westerly deviation is always subtractive from compass course to get magnetic.

In line with the proposed card, the compass rose on the chart should be marked from 0° at north continuously to the right to 360°, omitting the present system of points. The sailing directions should give courses and bearings in degrees, and not in points. The azimuth tables would require only a change in the rules given at the bottom of the page, as follows:

When the latitude and declination are of the same or contrary name—

In north latitude the azimuth is the tabulated value when the time is a.m.

In north latitude the azimuth is 360° minus the tabulated value when the time is p.m.

In south latitude the azimuth is 180° minus the tabulated value when the time is a.m.

In south latitude the azimuth is 180° plus the tabulated value when the time is p.m.

No other change in the tables would be necessary. Such tables as that on page 8 of Bowditch, and tables 1 and 5A, would be eliminated.

It is believed that the proposed marking of the compass card would result in greater accuracy in navigation in its relation to the compass. Courses would be laid in degrees, and more accurately noted, as the approximate course of S.W. by W. ¼ W. "a little westerly," for example, would be replaced by the exact course of 240°. Chances of error in the application of the deviation to compass courses would be lessened. Conversion of points into degrees, and the reverse, would be eliminated from the problem. Boxing the compass would be a matter of a few minutes' instruction to the layman of average intelligence. Sailing directions would be simplified. All work in relation to the compass would be facilitated.

The Nilgiri Mountain Railway.

An interesting paper was recently read before the Institution of Civil Engineers by Mr. W. J. Weightman, M.Inst.C.E., on The Nilgiri Mountain Railway.

The author stated that this railway was notable as being the first Abt-rack railway constructed in India, and, at present, the longest of its class in the world. It was, moreover, the first for which all the plant and material was manufactured in England. The price paid for the steel rack was £14 10*s*. 9*d*. per ton, f. o. b., plus a royalty of £5 2*s*. 9*d*. per ton. This rate was considerably lower than those quoted by the German firms, who had hitherto had a monopoly for this sort of work. The line was one of the few using wooden instead of steel sleepers.

The railway was chiefly designed to serve the important towns of Ootacamund, the summer headquarters of the Madras Government, Coonoor, Kotageri and Wellington, the latter being the military sanatorium for South India and Burmah. It was sixteen and three-

quarter miles long, and from its starting point at Mettapollium on the Madras Railway, ascended nearly 5,000 ft. to the plateau on the Nilgiri Hills. The first four and three-quarter miles were adhesion-line with gradients not exceeding 1 in 40; the remaining twelve miles were built on the Abt-rack system, and had a ruling gradient of 1 in 12½. The metre-gauge was adopted, and of the whole line nine miles consisted of curves. Details were given of the survey and laying out of the line, the operations for which were of a very arduous character, owing to the dense jungle and steep hillsides which had to be traversed.

The formation-width was everywhere sixteen feet, and as the rainfall was frequently six inches in as many hours, the greatest possible care was taken to see that it was effectually drained. There were twenty-three large bridges and 113 small ones. There were nine tunnels on the line, the longest being 325 ft. They called for no special remark as regarded their construction. It was noticed, in working, that the air in the tunnels got very bad when the engine had a full load, especially if fuel had just been added. This was due to the continuous up-draught caused by the incline, which made the smoke, etc., travel at the same pace as the train. It did not cause much inconvenience, owing to the shortness of the tunnels. The cost of the line was approximately £15,000 per mile; and a contemplated extension of eleven and a half miles was estimated for at £11,000 per mile.

The chief engineering interest centred in the permanent-way, which consisted of 50 lb. steel, flat-footed rails, 28·14 ft. long, laid on Burmese "Pyngadu" sleepers, 6 ft. by 8 in. by 4½ in., the last dimension being increased to six inches on the Ghat section, where the sleepers had also to carry the rack. The rack-bars were of steel, ten feet long and 0·87 in. thick, with a tensile strength of thirty tons per square inch with machine-slotted teeth. The greatest care was exercised in their manufacture as regarded pitch, shape of teeth, length of bar, and position of bolt-holes. The whole of this material was made by Messrs. Cammell and Co., of Sheffield, who devised a special machine for slotting the teeth. The cost of the double rack was 16*s.* per yard. The spring entering-tongues cost £32 15*s.* 2*d.* each. Full details were given of the method employed for laying the permanent-way, which had to be carried out with the greatest precision, the whole being considered in the light of a machine of which every part had to work with machine-like accuracy.

The locomotives were of the type known as "combined" Abt engines, that was, they could run either on rack or on ordinary line. Each engine had six wheels, two feet six inches in diameter, the trailing pairs being coupled. A jet of hot water was successfully used to decrease the wear of the tires, on the 328-ft. curves, due to the somewhat long-wheel base of ten feet. The total weight of the engines, including 625 gallons of water and one ton of fuel, was thirty-three tons. They were made by Messrs. Beyer, Peacock and Co., of Manchester, and cost £2,600 each. The rolling stock at present consisted of four rack-locomotives, sixteen goods-waggons, four first-class coaches, four composite coaches, and four brake-vans. Two passenger trains and two goods trains were run each way daily. The speed was limited to eight miles an hour on the Ghat section, and twenty miles an hour on the adhesion section. The passenger fares charged were Rupees 10, 5, and 1 for first, second, and third class respectively, for the ascending journey, and half those fares for the descending journey.

The author explained at length the method of working the line and the system of braking adopted. Before the

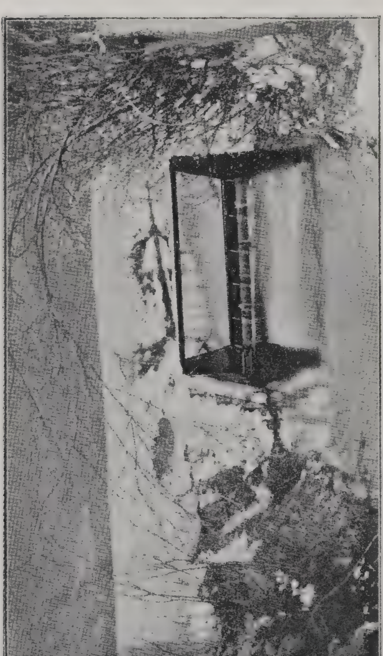


FIG. 1.—WEIR AT HEAD OF BIG DITCH, BIG COTTONWOOD CREEK, UTAH

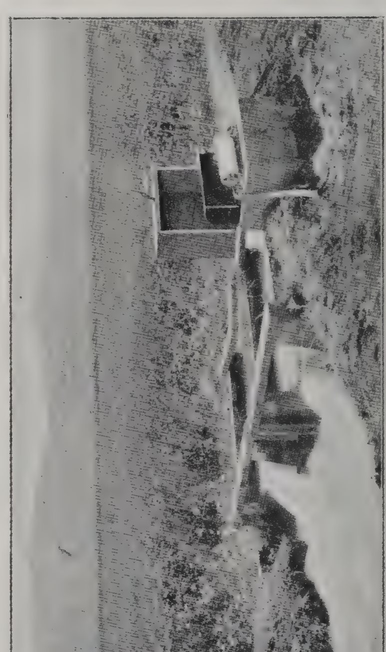


FIG. 2.—MEASURING WEIR AND REGISTER, MONTANA AGRICULTURAL EXPERIMENT STATION

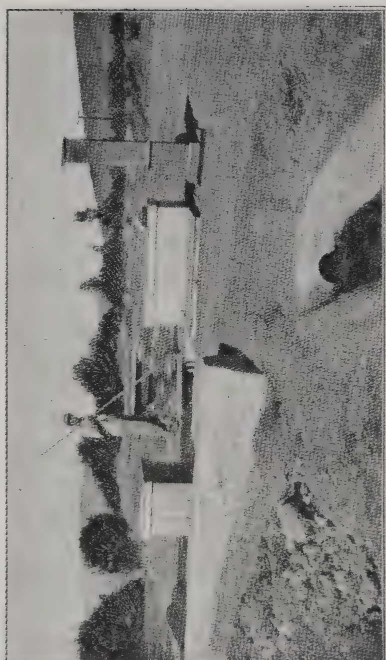


FIG. 3.—MEASURING FLUME AND REGISTER, GAGE CANAL, NEAR RIVERSIDE, CAL.

FIG. 4.—RATING FLUME NO. 1, KICKING BIRD CANAL, COLORADO.

line was opened for traffic a series of brake experiments was made with a fully-loaded train of 100 tons gross weight. With an ascending train at speeds of 6, 8, and 10 miles per hour on a 1 in $12\frac{1}{2}$ gradient, stops were made in 24, 36, and 60 ft. respectively; with a descending train at various speeds ranging from 4 to 12 miles per hour, relative stops were made in 54 ft., increasing to 425 ft.

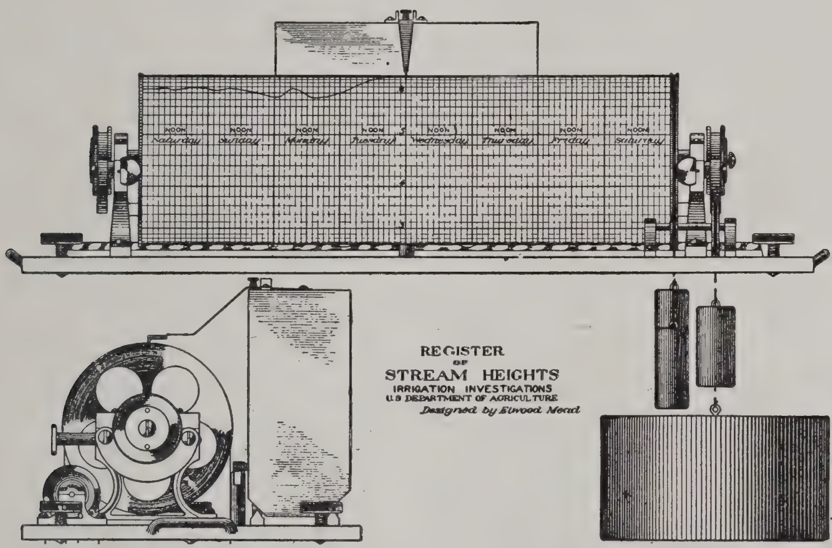


FIG. 5.—INSTRUMENT UTILISED FOR REGISTERING DAILY QUANTITIES OF WATER USED FOR IRRIGATION PURPOSES.

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Measurement of Water in Irrigation.

A very valuable report has just been issued by the United States Department of Agriculture on the Use of Water in Irrigation.* It is accompanied by numerous illustrations and tables, and amongst other phases of the subject, describes some of the instruments employed in recording amounts of water used. Some of these instruments we here illustrate. They are intended to continuously and automatically record the quantity of water used at weirs and flumes for irrigation purposes. It has not been found practicable to use a meter to measure the volume delivered, therefore in the United States it has been the practice to place a weir or flume in each canal, and then, by means of suitable instruments, keep a continuous record of the depth of the water delivered. In the instrument (Fig. 5) the rise and fall of the water in the ditch or lateral raises and lowers a float and counterweight. The latter are connected by a cord, which passes over the end of a cylinder, which is revolved by the cord's movement as the float rises and falls with the changes of depth in the stream. Around this cylinder is fastened a paper divided into rectangular spaces, the time divisions being parallel to its axis, and the depth division at right angles thereto. The pen or pencil making the record is moved along this cylinder by clockwork, passing from one end to the other in a week, when the paper is changed, and the pen returned to the starting point. The fluctuation in discharge creates a zigzag line, a wide variation in depth sometimes causing the cylinder to make

* London, P. S. King & Son. 7*s*. 6*d*.

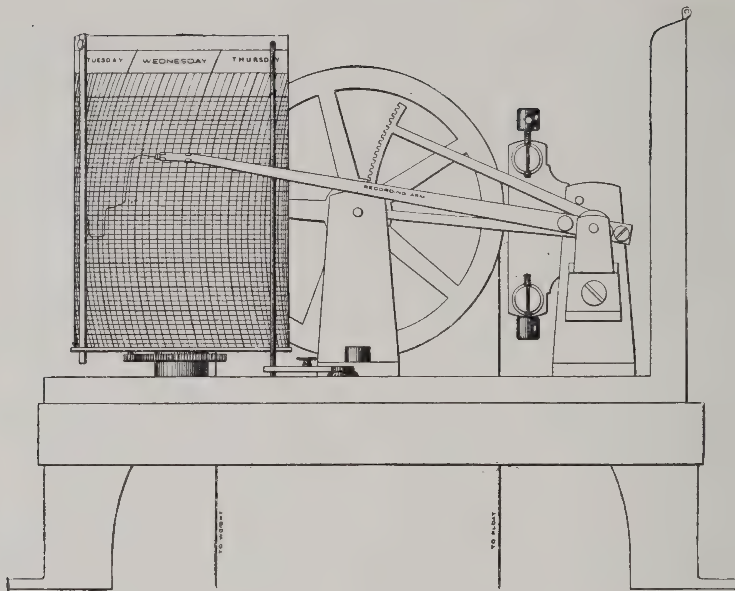


FIG. 6.—RICHARD BROS'. IRRIGATION WATER REGISTER.

a complete revolution. As the pen or pencil follows this and records it, any number of revolutions could be made without a loss of the record. A number of registers of other patterns are also used. The Richard Brothers' register (Fig. 6) is utilised in the measurements in Arizona, the instruments being loaned by the University of Arizona. The "Wyoming" nilometer (Fig. 7) is used at the Wyoming and Nebraska stations. The "Irving" register (Fig. 8) is used on the Gage Canal in California. The "Friez" register (Fig. 9) is a new form, which will be used in the investigations of the United States Government Department next year.

* * *

The Liberty and Property Defence League.

This League has just issued its Eighteenth Annual Report, the greater part of which is devoted to a record of the action taken by the Parliamentary Committee. Lists of the bills opposed by the League during the chief session of 1900 are grouped with short summaries of the proposals and effects involved, according as they affected land and houses, commerce, trade and industry, etc. In connection with the former,

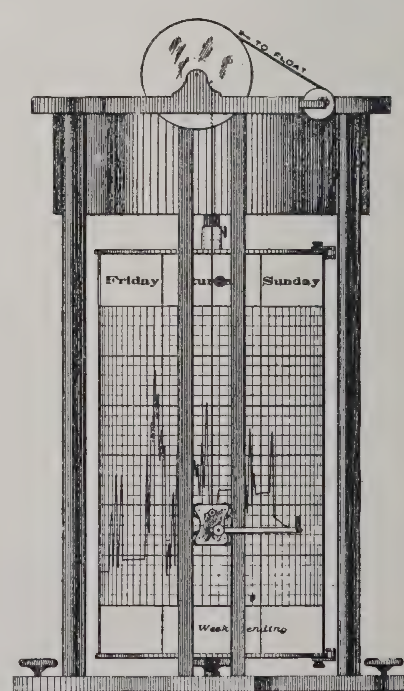


FIG. 7.—THE "WYOMING" NILOMETER FOR MEASURING WATER USED IN IRRIGATION.

special attention is called to the Agricultural Holdings Bill and the Borough Funds Bill, of which the first mentioned became law, and the latter was defeated. The grounds of opposition to the Government measure were that it was an example of unnecessary legislative interference with contracts, and that it was an example of the pernicious system of legislation by reference. The defeat of the Borough Funds Bill, the League claims, was wholly owing to its action in getting "several pages of amendments put on the paper." The report of the Select Committee inquiring into boiler registration is quoted with satisfaction. The Committee, it will be remembered, reported strongly against the advisability of legislation, holding it of the greatest importance to maintain the responsibility of the boiler-user for the condition and safety of the boiler which he works, and believing that legislation giving any Government department control over the inspection of boilers would be a grave mistake, and that State certification of registration, unless accompanied by State control, would not be of any practical value. In inviting membership, the Report states that it is only by vigilant watching and prompt action, such as that of the League, that many Bills to which property owners take exception are prevented from becoming law. The Report also pays special attention to the proceedings of the Municipal Trading Committee, and to the success of the various Electricity Supply Bills, the passage of which the League claims to have materially assisted.

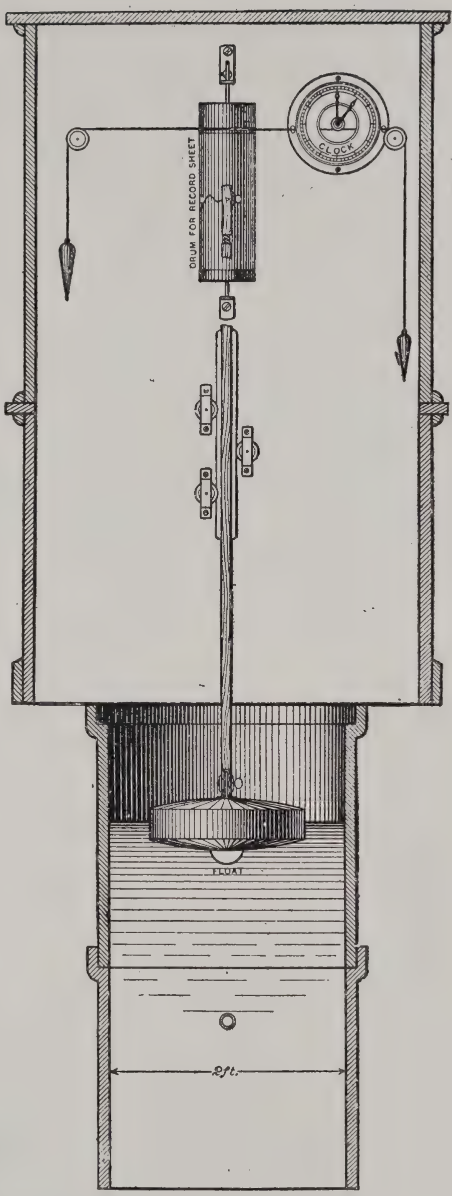


FIG. 8.—THE "IRVING" REGISTER.

Shop Libraries.

That is a good idea adopted by the proprietors of some large machine and engine works to have a shop library on the premises for the use of the workmen. Especially is this an admirable scheme for extensive manufactories and mills which are located at a distance from cities and towns having public libraries.

"I have in mind," says a writer in our American contemporary, "Modern Machinery," "a large machine shop in the East where the proprietors provide

a free library on the premises for 'all hands.' A large, plain room is fitted up with shelves and a librarian's desk. The books are classified under heads of 'History,' 'Biography,' 'Travels,' 'Fiction,' 'Mechanics,' 'Engineering,' 'Magazines,' 'Encyclopædias,' 'Dictionaries,' etc. New books are added from time to time, and the workmen have the privilege of recording in a suitable manuscript book the titles of books which they are desirous to have placed in the library. These, of course, are submitted to the judgment of the proprietor, the purchase of them being optional with him.

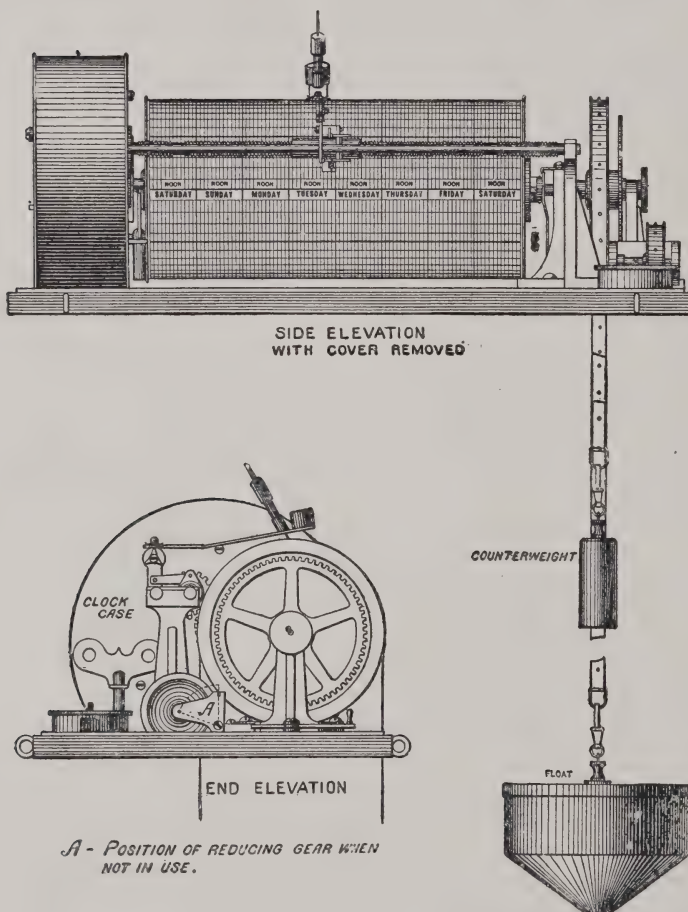


FIG. 9.—THE "FRIEZ" WATER REGISTER.

"Every workman is provided with a catalogue.

"Books may be kept for two weeks and then 'renewed,' if desired, at the expiration of the allotted time. In order to avoid confusion and to save time, the library is open every Saturday for two hours when the regular work-day hours have ended.

"Another good thing about this shop library is that any workman employed on the premises, or any outsider interested in the usefulness of the library, may contribute a book or a set of volumes on the approval and acceptance of the proprietor. The chief aim of the proprietor is to furnish his workmen and apprentices with elementary and educational works on natural philosophy, mechanics, machinery, drawing, mensuration, engineering, chemistry, and applied science; after that, books for family reading and amusement.

"The only regulations or stipulations in connection with this library are that if books are kept beyond the allotted time a fine of 25 cents per day is imposed, and no other book can be loaned until the fine is paid. A second regulation is that books must be returned as far as possible in good, untorn, and unstained condition. The fine of 25 cents per day may appear high, but a strict enforcement precludes all

disagreeable friction and misunderstandings. The workmen appreciate this library, and are interested in it, use it freely, and are proud to refer to it as 'Our Library.' The books are all kept in good condition. The librarian has a simple but very practical system, and is paid for his services. The 'fine money' is devoted to the purchase of new books.

"Now, is there any reason why every large manufactory and mill should not have a library—one instituted, organised, and conducted by themselves?

"The writer, some years ago, in Brooklyn, N.Y., organised a 'Working-men's Club,' and with little effort raised a library of 1,000 books within thirty days. And this in a city which had a public free library of 50,000 books! If this could be done in a city of churches, schools, books, magazines, and newspapers, what could be done for a manufactory in a suburban locality, where there are hundreds of persons at work who have no ready access to a free library?

"There are few corporations, if any, who would not give a library room on the factory premises for the exclusive use of their employés. Four requisites only seem necessary:

"1. A large, suitable room on the premises, apart from the general and private offices, and fitted up appropriately for the purpose.

"2. A competent managing librarian.

"3. A judicious selection of classified books.

"4. A system such as is followed in the machine works before referred to.

"Here is a little calculation for thinking workmen: Number of employés, 1,000; number of books contributed by workmen on the premises, 250; number of books contributed by the company, or proprietors, or friends, 500; number of books donated by publishers and those interested in the scheme, 500; total number of books, 250 + 500 + 500 = 1,250 books as a starter.

"The primary object of a workmen's library should be the getting together of books which treat on his trade, occupation, and calling; and then books for his family, to the positive exclusion of trashy, unwholesome, and undesirable literature.

"Magazines and trade papers are nearly always gladly donated for working-men's libraries.

"The daily newspaper has the largest field and the greatest patronage by all classes of society. But the daily newspaper can never take the place of the instructive journals and trade literature in imparting useful knowledge to workmen and tradesmen.

"There are hundreds of places more or less remote from cities where the life is essentially and absolutely factory life, where men and women toil monotonously day after day, and where instructive books and healthy, clean literature should be as accessible as the ten-cent novels and silly romances which are so eagerly procured, and, unfortunately, so eagerly read. Hence the shop library becomes a boon of great value not only to the workmen themselves, but also to their families."

ELECTRO-MOTOR *versus* STEAM-ENGINE DRIVING.

By R. GORDON SHARP.

THE electro-motor has been displacing the steam-engine lately to such an extent, that we are almost at the point of raising the motor to the significance of a prime mover. The connecting wire, or cable, between the motor and the dynamo at the engine, or other prime mover, is so small and unobtrusive that it is hardly noticeable.

It is quite a common thing to hear of cases in which a number of small and worn-out engines, of an obsolete type, have been thrown out and replaced by motors, with apparent economy in coal and water consumption as the result. In these cases, the dynamos for supplying current to the motors are hitched on to engines of latest design, which embrace all the best known methods and appliances for efficient working. We seldom get to know how much of the saving is due to the improved engines, boilers, high-pressure steam, and such like, and how much to the electrical part of the new plant. We are quite as much in the dark as to how much extra capital has been sunk in the new installation.

No one has the least doubt of the fact that there are any number of cases in which the substitution of motor driving for direct steam-engine driving must result in a saving of money. There is as little question about its wide and almost universal adaptability, its compactness, cleanliness, and such like. These qualities are obvious, but in many cases they have to be secured at considerable cost. Whether they are worth the price is quite another question. The financial test is, after all, the crucial one, and yet electrical engineers, in some instances, go the length of advising the adoption of electrical driving, where it will not stand the searching inquisition of the profit and loss account. They do so on general grounds, such as, "adopt electric driving, and you will very soon find out its advantages in extra output, greater adaptability," and so on, but it is not always possible to show on paper that there would be a money or other palpable advantage.

Perhaps the best way of following up the matter will be by taking a case in point.

A "mill" for wood-working purposes is considered by many to be a very suitable subject for the adoption of electric driving of the various machines. In a shop of this description the machines have generally to be a good deal scattered over the floor, and often they work intermittently. These two considerations are admittedly in favour of electric driving.

The diagrammatic plan (Fig. 1) shows the number and arrangement of machines as proposed to be laid down in the corner of a small shop for carriage and waggon building. The machines have been placed on the plan in the most approved order and position for turning out work, while giving comfortable floor space for templating and piling up the timber beside the machines. The following is a list of the machines, with the approximate maximum brake horse-power required by each.

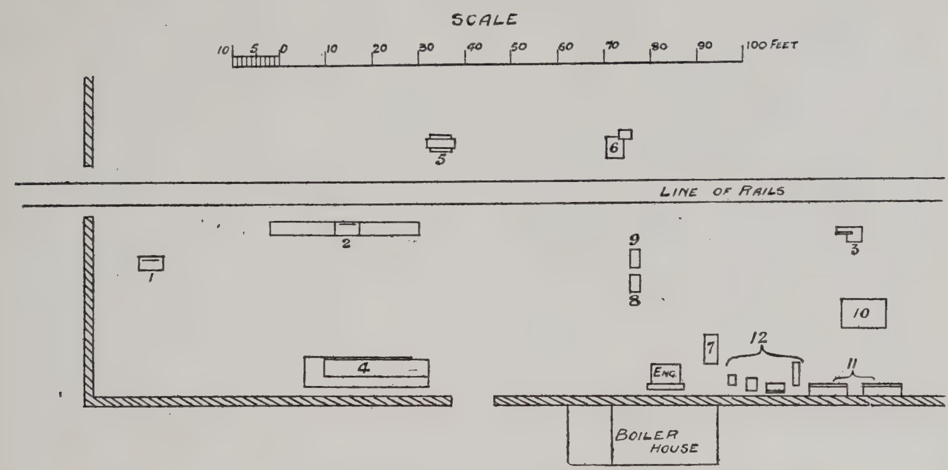


FIG. 1.—ARRANGEMENT OF WOOD-WORKING MACHINERY.

WOOD-WORKING MACHINERY.

No.	Machines.	Maximum b.h.-p. Required.
1	Cross-cut saw	12
2	Ripping ,, ...	15
3	Band ,, ...	7
4	Four-side planer	12
5	Panel ,, ...	12
6	Tenoner	6
7	Morticer and borer (large)	6
8	,, ,, ,, (small)	3
9	Borer	3
10	Irregular moulder	5
11	Two turning lathes	3
12	Four machines for grinding tools.....................	2
	Total	86

The h.-p. for the several machines has been calculated from the size and speed of belts as used in actual practice. According to this computation, the h.-p. comes out very high. In fact, it is, in several cases, much higher than seems necessary. It seems, however, to be a case of the survival of the fittest, as it is likely that makers have found it necessary to provide a large margin of power, so as to avoid frequent breakdown. For the same reason, a reliable engineer would take care to have ample margin of power if motors were being installed, and this, too, with the knowledge that motors are now made so as to take 50, or even higher, per cent. overload for a short period, without any bad effect. At all events, the figures are sufficiently near the actual to admit of comparative estimates being made of the necessary capital expenditure and working cost, under the three different conditions about to be considered. Any adjustment of the power which might be made would affect the general result so little as to be of no account.

There are three outstanding methods, any of which might be adopted for driving the machinery, viz. :—

(A) By a steam-engine and line shafting in the ordinary way.

(B) By applying an electro-motor in the place of a steam-engine.

(C) By attaching a separate electro-motor to each machine, or (as in the case of very small machines) to groups of machines.

In considering methods (A) and (B), it must be reckoned that, although the aggregate power required by the machines appears as 86 horse-power, it would be almost a physical impossibility for the whole power to be required at one and the same time. If one machine happens to be working at its maximum, others will probably be working very light. This is found to be the case in practice.

It would, therefore, be a mistake to lay down an engine or electro-motor to give 86 h.-p. at the machines, unless allowances were being made for extensions, which cannot be considered here. If plant for 60 h.-p. (maximum), or about two-thirds of the aggregate, be provided, that would be ample. This will, therefore, form the basis of the estimates for methods (A) and (B), so far as capital expenditure is concerned.

In method (C) any one machine may be required to work at its maximum at any time, thus making it necessary to provide motors accordingly.

Each motor must be rated somewhere near the maximum power of its machine, perhaps a little under it, as there would be no difficulty about taking a temporary overload of 25 to 50 per cent.

In making up the estimates the figures will be taken from the present ruling prices, but the difficulty of presenting conclusive statements will be appreciated by all who have to deal with the preparation and consideration of estimates. Two makers of dynamos or motors of equal power, adaptability, etc., will differ as much as 50 per cent. in price.

In connection with the working cost, the maximum power necessary has been placed at 60 b.h.-p., but the average will be much less than this, and may be taken at 45, which is three-fourths of the maximum. While this is so, there will be a considerable amount of time during which the machines must be standing for readjustment, etc. It should not, however, exceed one-fourth of the total working hours. Taking the total working hours at 2,700 per annum, each machine will be idle for 675 hours, and they will collectively require 45 b.h.-p. for 2,025 hours.

On this basis the following calculations have been made as to working cost.

METHOD (A).

Capital Expenditure.	£
Boiler house, coal bunker, etc. ...	80
Boiler with steam pipes, valves, feed-pump, feed-heater, etc., complete and in position	320
Engine in position	280
Extra on roof to take overhead shafting	78
Shafting, pulleys, bearings, etc....	180
Belting	104
Spare parts for engine, etc.	50
Total	£1,092

METHOD (A).

Working Cost Per Annum.	£
Interest on capital expenditure, £1,092 at $3\frac{1}{2}$ per cent.	38·2
Over all depreciation, 4 per cent. on $\frac{£1,092}{1} \times \frac{3}{4}$	32·8
Over all maintenance, £1,092 at $2\frac{1}{2}$ per cent.	27·3
Coal at 3 lbs. per h.-p. per hour, and 12*s*. per ton	103·6
Water, oil, packing, etc. (water at 4*d*. per 1,000 gallons)	14·3
Attendant's wages	65
Total	£281·2

In this case 6 h.-p. has been allowed for driving the engine alone, and 8 h.-p. for the shafting, the total horse-power hours working out to 128,925 per annum.

METHOD (B).

Capital Expenditure.	£
Proportionate share of cost of—	
Boiler house	20
Boiler, etc...........................	190
Power house	30
Engine and dynamo	500
Switch-board........................	15
Spare parts for engine and dynamo	90
Motor (including starting switches, etc.)	260
Main cables from dynamo to motor	160
Extra on roof to take overhead shafting	78
Belting	104
Main shafting, pulleys, bearings, etc.	180
Spare armature for motor	70
Total	£1,697

METHOD (B).

Working Cost Per Annum.	£
Interest on capital expenditure, £1,697 at 3½ per cent.	59·4
Over all depreciation, 4 per cent. on £1,697 × ¾	50·9
Over all maintenance, £1,697 at 2½ per cent.	42·4
Coal at 3 lbs. per h.-p. per hour and 12*s*. per ton	125·0
Water, oil, packing, etc. (water at 4*d*. per 1,000 gallons)	13·0
Attendant's wages, £65/3	21·7
Total	£312·4

METHOD (C).

Working Cost Per Annum.	£
Interest on capital expenditure, £1,940 at 3½ per cent.	67·9
Over all depreciation, £1,940 × ¾, at 4 per cent.	58·2
Over all maintenance, £1,940 at 2½ per cent.	48·5
Coal at 3 lbs. per h.-p. per hour at 12*s*. per ton	109·5
Water, oil, packing, etc. (water at 4*d*. per 1,000 gallons)	13·0
Attendant's wages, £65/3	21·7
Total	£318·8

The power required at the machines is 45 h.-p., while 8 h.-p. is absorbed in the shafting, making a total of 53 h.-p. to be given off at the motor for 2,025 hours per annum. During this, the combined efficiency of the engine and dynamo is taken at 88 per cent., the motor at 85 per cent., and the cables, etc., at 97 per cent.

During the idle time of 675 hours, it has been estimated that 12·8 i.h.-p. would be required to keep the shafting, etc., at the normal speed.

The total horse-power hours work out to 156,560 per annum.

METHOD (C).

Capital Expenditure.	£
Proportionate share of cost of—	
Boiler house	20
Boiler, etc..............................	190
Power house	30
Engine and dynamo	500
Switch, etc., boards...............	50
Spare parts for engine, dynamo, and motors.......................	150
Motors (including starting-switches and wiring from distribution board)	770
Main cable from dynamo to distribution board...	160
Belting	30
Shafting, pulleys, and bearings...	40
Total	£1,940

In methods (B) and (C) it might be legitimate to reduce the coal per h.-p. hour below that given for method (A), on account of the higher efficiency of large engines. The amount in this example could not be of much account.

During the 2,025 machining hours an average of 45 total h.-p. would be required at the machines.

The combined efficiency of the engine and dynamo has been taken at 88 per cent., and it has been assumed that the average efficiency of all the motors would not exceed 80 per cent., seeing they would be generally working very much under their maximum power besides being of comparatively low power. The efficiency of the cables, switches, etc., would be about 97 per cent.

There would be very little loss during the 675 idle hours, and it may therefore be ignored.

The total horse-power hours work out to 136,282 per annum in this case, allowing a slight amount for counter shafting.

In estimating the depreciation, it has been assumed in each case that three-fourths of the initial cost would have to be written off in 25 years, when the plant would be valued at one-fourth its original cost.

It will be seen that the annual

working cost by the three methods as estimated is as follows, viz. :—

Method (A)	....	£281·2
" (B)	....	312·4
" (C)	....	318·8

the ratios being approximately 100, 111, and 113 respectively.

The foregoing figures are admittedly only approximations, but they are perhaps as near the actual as can be gauged; in fact, they have been arrived at after very careful consideration of all the conditions obtaining in an existing example. If they err at all, it is in favour of electric driving, so as to avoid all unintentional partiality to the ordinary method of direct driving from a steam-engine.

The heavy capital outlay militates strongly against electric driving, while it would appear that it would also suffer on account of increased coal consumption.

This is not generally supposed to be the case. It is not an unusual thing to hear of 10, 15, and 20 per cent. savings in the coal bill by the adoption of electric driving. One would be quite prepared to accept this in the case of machinery which stands idle during a large proportion of shop hours, but even then the total sum saved is perhaps so small as to forbid the idea of spending more capital.

The practice of stating these savings in percentage is very convenient, but it is often very misleading.

The saving in wages due to firemen, engine tenders, etc., is also urged in favour of electric driving. Any saving in this direction can only come where there would be a large concentration of power, and in that case the wages bill is a very small proportion of the total working cost. It must also be borne in mind that the introduction of electricity means the introduction of a new and high paid class of labour.

In the particular case under consideration, one man could quite easily attend to both boiler and engine. The engine will run from meal hour to meal hour, practically without attention.

As a side issue, the warming of the shops has to be considered. In the case of heating being necessary, it would mean the putting in of special heating furnaces, if a steam boiler were not within easy reach. These furnaces cost a good deal, and they require some attention, which, in winter at all events, would be a slight offset against the attention required by a steam boiler.

It may be said that the power set aside for driving the shafting is very low, which it really is when compared with some figures which appear in connection with the efficiency of line shafting. These figures are frequently excessive, and in this case, at all events, the power is not very much under-estimated.

No single result can be applied to all cases. Each case should be minutely investigated in the light of local conditions and special requirements. In no case should electric driving be adopted without first considering every item which affects the working cost. One is apt to be carried away by promised percentage savings in coal, but these, when minutely examined, may turn out to be much less than the interest and depreciation on the extra capital.

In some cases, no doubt, extra cost of working may be more than balanced by extra out-put. This would not be so in the instance which has been considered, and the day has not yet come for the adoption of electric power-driving on purely æsthetic grounds.

K Gordon Sharp

PUMPS: THEIR CONSTRUCTION AND MANAGEMENT.

By PHILIP R. BJÖRLING,

Author of "Mechanical Engineer's Pocket Book." *

(*Continued from page* 90.)

CENTRIFUGAL PUMPS (*continued*).

AN ordinary centrifugal pump, by Messrs. Gwynne and Company, of London, operated direct by a single-cylinder inverted vertical engine, is illustrated in Fig. 68. Messrs. Gwynne's first combined engine and centrifugal pump was exhibited at the International Exhibition, 1862. The principal features of their combined engines and pumps are large wearing surfaces, a peculiar construction of piston—whereby a great reduction of friction is obtained—and small weight of reciprocating parts.

One of Messrs. Gwynne's centrifugal pumps coupled direct to one of their enclosed, silent, high-speed engines is illustrated in Fig. 69. The engine is of the double-cylinder, single-acting type, which is now so much in fashion.

A "Helical" centrifugal pump, manufactured by Messrs. John Cherry and Sons, Beverley, Yorkshire, is illustrated in sectional end view (Fig. 70), and reproduction from a photograph (Fig. 71). It consists of an ordinary impeller with taper sides, furnished with a screw on each side—hence the name "Helical." These screws are right and left handed and made to fit in the screw chambers, the external diameters being equal to the central openings for the inlet of the water to the impeller; the spindle on which the impeller and screws are firmly keyed also carries the driving pulley; this spindle works through two stuffing-boxes and glands, and an ordinary bearing, on the inside of the driving pulley. The casing is provided, in the usual fashion, with a suction and delivery branch. By removing the top half of the casing, access is given to the impeller and screws. In this example the impeller is 17 in. diameter; the screws in the inlets are 9 in. diameter, having each three threads. By careful experiments it has been found that a pitch of 6 in. for the screws gives the best results in a 6-in. pump. The screws act as a grip on the water and feeders to the impeller, and prevent any back slip of the water, hence a greater power of suction than the ordinary centrifugal pumps. To prove this power of suction it may be mentioned that the British Admiralty tested one of these pumps, and it picked the water up, after the pump had been stopped, at a distance of 30 ft. 6 in., much to the surprise of the Government inspector. As an example of the work which the "Helical" centrifugal pump will perform, one of the improved 6-in. pumps will discharge 2,000 gallons per minute to a height of 100 ft.

* Messrs. Whittaker & Co.

An arrangement of a large centrifugal pump and engine manufactured by Messrs. Gwynne and Company is shown in Fig. 72.

REMARKS ON CENTRIFUGAL PUMPS.

Centrifugal pumps are specially applicable for irrigation, the simplicity of their construction and consequent non-liability to get out of order being a special recommendation; drainage of low-lying and marshy land; pumping

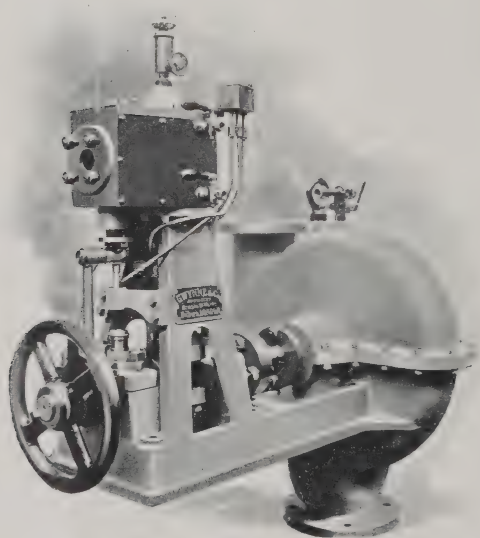


FIG. 68.—VIEW OF CENTRIFUGAL PUMP OPERATED DIRECT BY A SINGLE CYLINDER INVERTED VERTICAL ENGINE MADE BY MESSRS. GWYNNE & CO.

sewage from a low to a high level; emptying docks, canals, reservoirs, etc.

The original shapes of the vanes of the impeller were straight and radial, but it was soon found to be incorrect; next they were made straight, but at an angle to the radial line. Now they are, by some makers, made straight two-thirds of their length, then curved towards the periphery in an opposite direction to the line of rotation, for low and moderate lifts, and curved with the line of rotation for high lifts. Other makers curve the vanes the whole of their length; some make the curve by a simple radius, some make them by a curve struck by two radii; and, again, some prefer a regular curve all the way, of a peculiar construction.

The vanes should be as thin as possible, to avoid obstruction to the entering water, thereby preventing the stream from becoming broken and agitated in its passage through the impeller.

The passages through the impeller should be so proportioned as to gradually increase the velocity of the water until it arrives at the circumference, when a gradually decreased velocity should take place, until it enters into the delivery-pipe.

The casing is usually made in the shape of a helix, commencing at the top, and gradually increasing until it reaches the delivery-pipe.

At the highest point of the casing a cock or valve should be provided for letting out the accumulated air, or a connection by means of a small hole or passage between that point and the delivery-pipes.

The vertical height of suction should be made very slight; in fact, it is best to have the water running into the pump. The greatest depth from which an ordinary centrifugal pump can draw water, except when they are arranged in series, is 25 ft.; but in practice it should never exceed 20 ft.; except the pump with screws in the admission passages, which has raised water from a depth of 32 ft. with an efficiency of 45 per cent.

ADVANTAGES AND DISADVANTAGES OF CENTRIFUGAL PUMPS.

The advantages are:—

The large body of water which they are capable of delivering, as compared with their size and prime cost.

They can deliver sandy, gritty, and muddy water without injury to the machine.

They are easily fixed, and require very small and inexpensive foundation.

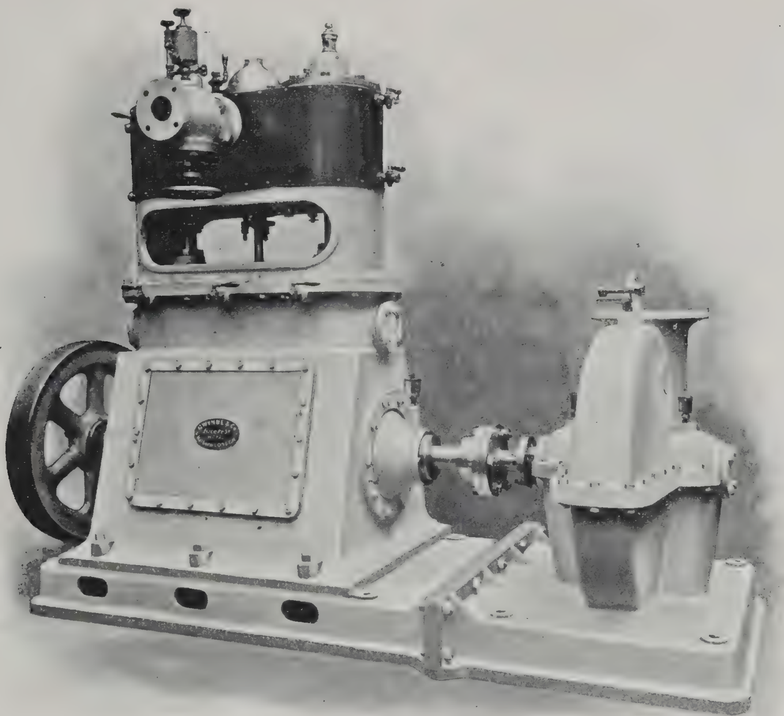


FIG. 69.—VIEW SHOWING ONE OF MESSRS. GWYNNE'S CENTRIFUGAL PUMPS, COUPLED DIRECT TO ONE OF THEIR HIGH-SPEED ENGINES.

Submerged centrifugal pumps require no foot-valve; where impure water is pumped, this is a great consideration.

They do not require charging with water before starting.

They are, however, difficult to clean and repair, having to be lifted out of the pump well if the water is not let away from it.

Centrifugal pumps with horizontal spindle above the level of the water require little foundation work.

They are very easily moved.

They can be fitted on a trolley, and the suction-pipe furnished with a universal joint, that it can be raised and lowered at will.

The disadvantage is that they cannot raise water to any great height.

PULSATING STEAM-PUMPS.

These pumps, or, more correctly speaking, these pumping engines, are simply ingenious and compact arrangements of the old "Savery" atmospheric engine, or, as the inventor called it, the "Miners' Friend."

"The Miners' Friend" is illustrated in Fig. 73, the blocks of which have been kindly lent to the writer by the Pulsometer Engineering Company, who describe it in one of their pamphlets in the following manner:—"One of the first steam-engines employed for

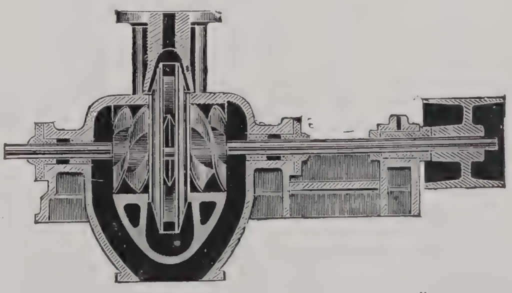


FIG. 70.—SECTIONAL END VIEW OF "HELICAL" CENTRIFUGAL PUMP, MADE BY MESSRS. JOHN CHERRY & SONS, BEVERLEY.

pumping water is illustrated at the side. Passing over the apparatus for generating steam—shown in the background—the construction of the engine will be seen to be not unlike that of the pulsometer steam pump.

"In Savery's apparatus the action was as follows:—Steam from the boiler was admitted above the surface of the water, driving the same up the delivery-pipe. The steam-valve was then shut, and the suction-cock opened. At the same time a spray of water was allowed to flow over the chamber, causing the formation of the necessary vacuum. The water rushed into the chamber, and the suction-cock was then shut, and the steam-valve opened. A man, of course, had to be in constant attendance to operate the cocks."

The pulsating steam-pumps are not, by any means, efficient thermo-dynamic engines; on the contrary, they are very wasteful with steam. However, they have many redeeming qualities, such as cheapness in first cost, simplicity in construction, and, if in the first instance correctly made, they are very positive and certain in their action, and not liable to get out of order.

They are especially good as emergency pumps, as, for instance, in case of a pit or quarry getting suddenly flooded, or for emptying foundations, or any temporary works of such description, when a large body of water is required to be raised in a short space of time.

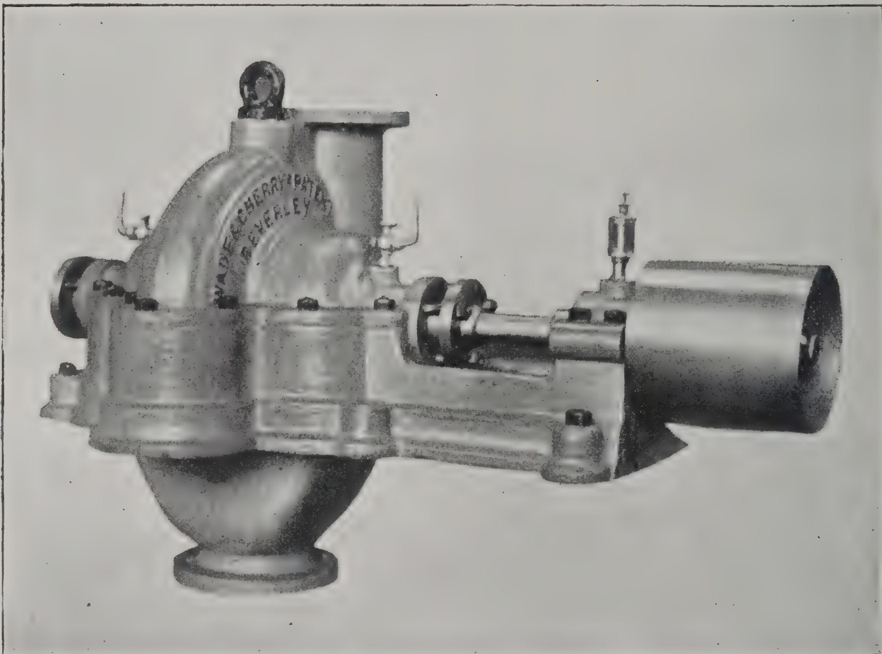


FIG. 71.—VIEW OF 6 INCH "HELICAL" CENTRIFUGAL PUMP, MADE BY MESSRS. JOHN CHERRY & SONS, BEVERLEY.

They are also frequently adopted for sinking pit shafts, and emptying wells when pumps are being fixed in them, as they are quickly and easily raised and lowered, also handy to fix. Of late years several have been applied for clearing dip-workings in mines from water.

The height of suction should be as little as possible, but should never exceed 18 to 19 ft., although in some cases they have been known to draw

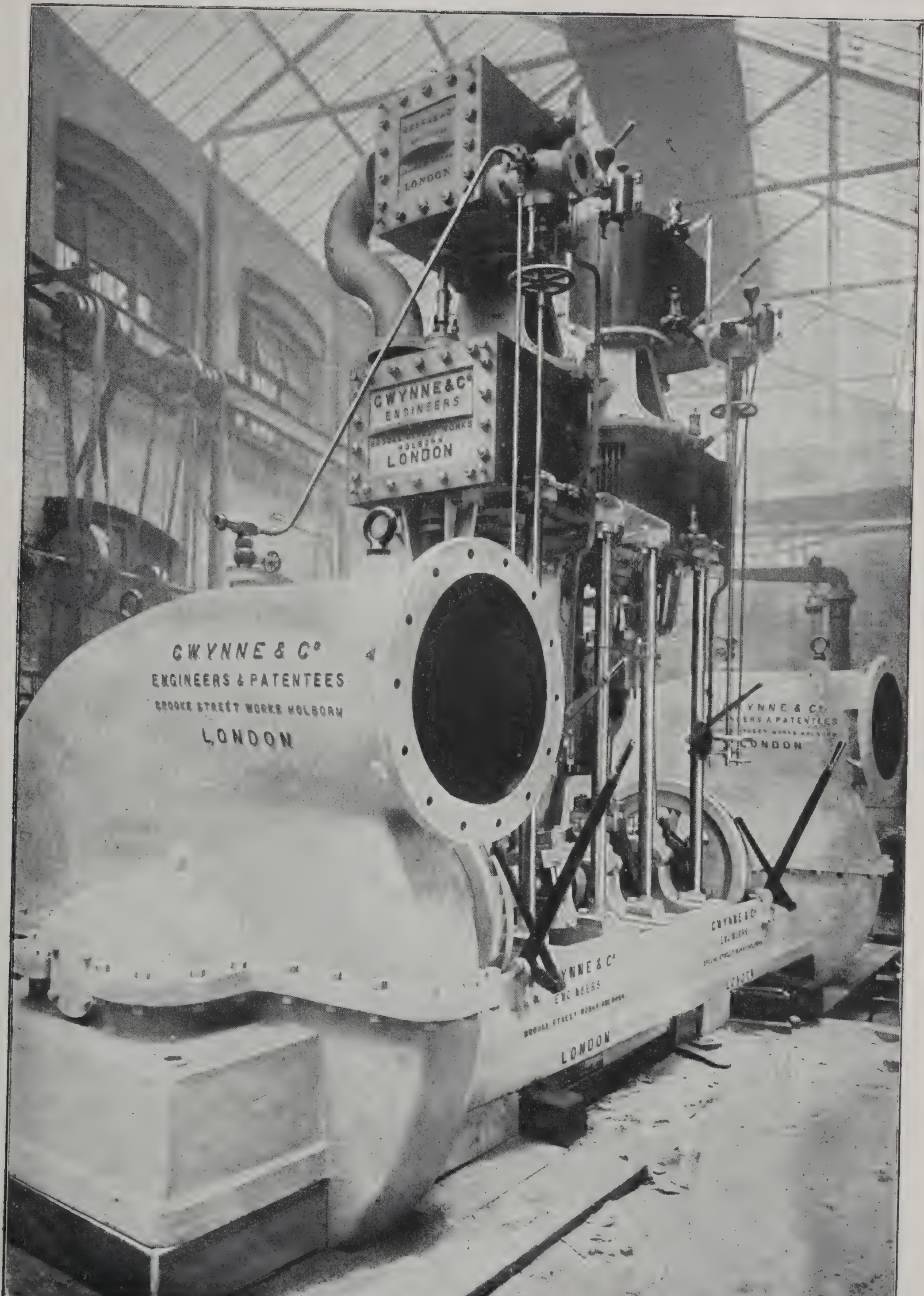


FIG. 72.—VIEW OF LARGE CENTRIFUGAL PUMPING SET, MADE BY MESSRS. GWYNNE & CO., LONDON.

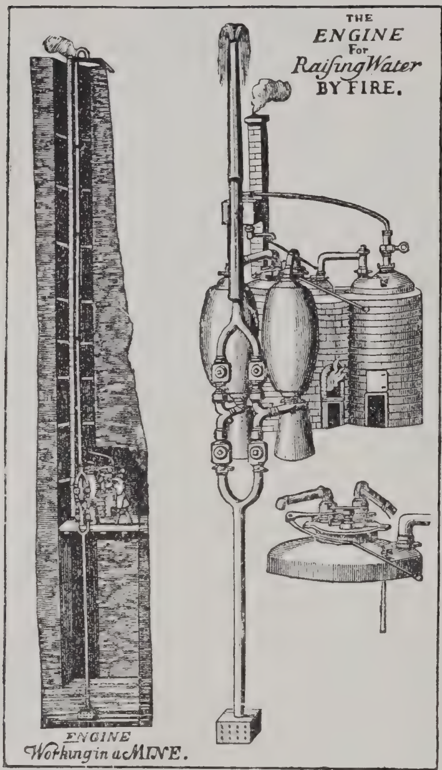


FIG. 73.—VIEW OF THE "SAVERY" ATMOSPHERIC ENGINE, "THE MINERS' FRIEND."

water 25 ft., but not with any degree of certainty.

Hot liquids up to 165 degrees Fahr. have been forced, where the pump has been level with the same.

The pulsating steam-pump was, we believe, originally invented by Mr. G. V. Long, of the United States Navy, and was illustrated and described in the "American Journal of Science" in the year 1828; but that pump, like Savery's "Miners' Friend," was not self-acting.

The next attempt in the way of pulsating steam-pumps was made by Mr. Burdon; this pump was self-acting or automatic.

DOUBLE-ACTING PULSATING STEAM-PUMPS.

The first really practical pulsating steam-pump was the one invented by Mr. Hall, which was introduced and is manufactured by the Pulsometer Engineering Company, Ltd., of London, who have given it the name "Pulsometer." This pump is illustrated in Fig. 74, which is a sectional elevation of the valve-chest, and Fig. 75, end view of valve-chest. It consists of a single casting, called the body, which is composed of two chambers joined side by side, with tapering necks bent towards each other, and surmounted by another steam-chamber A, common to the two, in which there is fitted a ball-valve B, shown in Fig. 74, so as to be capable of oscillation between seats formed in the junction. Downwards the chambers are connected with the suction-passage, wherein the inlet or suction valves are arranged. A discharge chamber, common to the two working chambers, and leading to the discharge pipe, is also provided, and this also contains one or

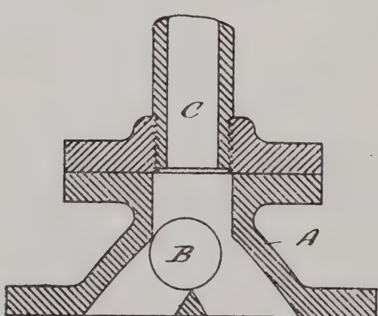


FIG. 74.—SECTIONAL ELEVATION OF THE VALVE-CHEST OF PULSATING STEAM-PUMP, MADE BY THE PULSOMETER ENGINEERING CO., LTD., LONDON.

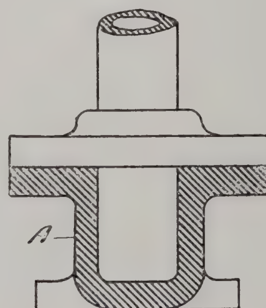


FIG. 75.—END VIEW OF VALVE-CHEST OF SAME.

two valves, according to the purpose to be fulfilled by the pump. The air-vessel communicates with the suction-pipe. The suction and discharge chambers are closed by hinged covers accurately fitted to the outlets by planed joints, and readily removed when access to the valves is required. Small air-cocks are screwed into the cylinders and air-vessel.

The pump, being filled with water, is ready for work. Steam is admitted through the steam-pipe C—by opening to a small extent the stop valve—passes down that side of the steam neck which is left open by the position of the steam ball—which is the right-hand side in the illustration—and presses upon the small surface of water in the chamber which is exposed to it, depressing it without any agitation, and consequently with but very slight condensation, and driving it through the discharge opening and valve into the rising main.

The moment that the level of the water reaches the level of the horizontal orifice which leads to the discharge, the steam blows through with a certain amount of violence, and being brought into intimate contact with the water in the pipes leading to the discharge chamber, instantaneous condensation takes place, and a vacuum is in consequence so rapidly formed in the just emptied chamber, that the steam ball is pulled over into the seat opposite to that which it had occupied during the emptying of the chamber, closing its upper orifice, and preventing the further admission of steam, allowing the vacuum to be completed ; water rushes in immediately through the suction-pipe, lifting the inlet valves, and rapidly fills the chamber again. Matters are now in exactly the same state in the second chamber as they were in the first, and the same results ensue. The change is so rapid that, even without an air-vessel on the delivery, but little pause is visible in the flow of water, and the stream is, under favourable circumstances, very nearly continuous. The air-cocks are introduced to prevent the too rapid filling of the chambers on low lifts, and for other purposes, and a very little practice

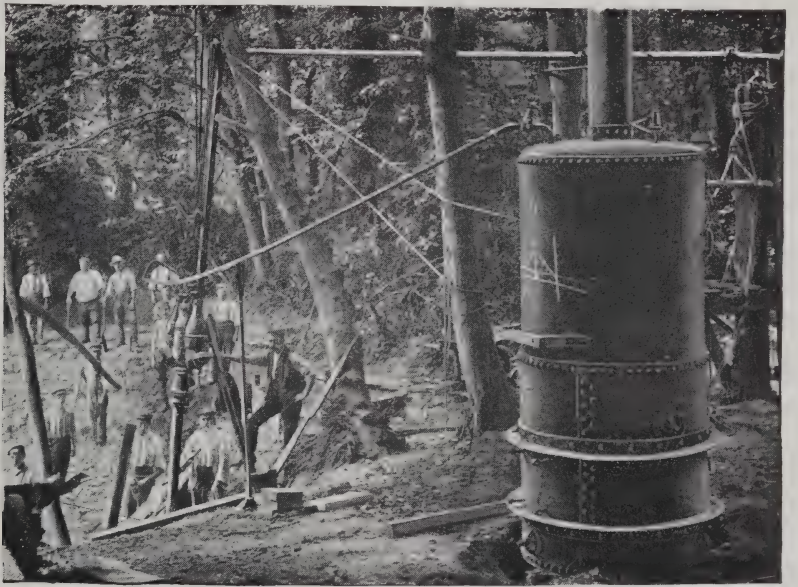


FIG. 76.—VIEW OF THE "PULSOMETER," AS USED FOR PUMPING MUD OUT OF A LAKE FOR CLEANING PURPOSES.

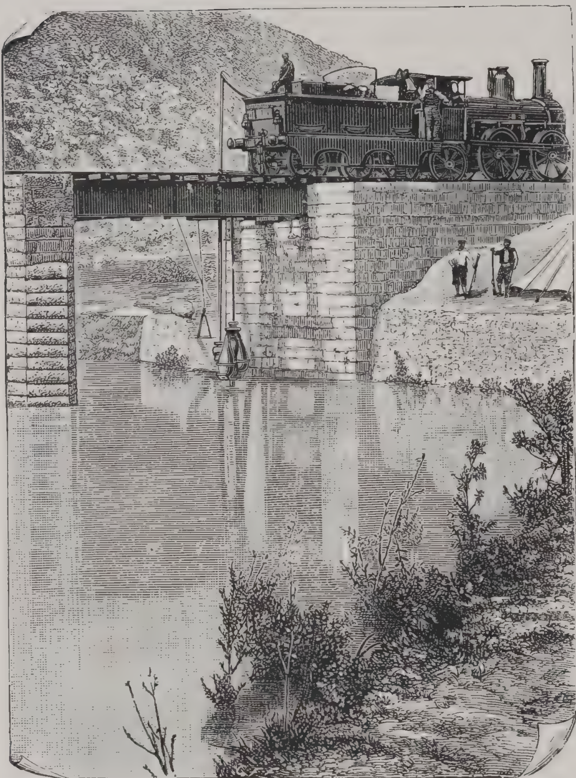


FIG. 77.—VIEW SHOWING "PULSOMETER" ARRANGED FOR SUPPLYING THE TENDERS OF LOCOMOTIVES WITH WATER FROM A RIVER.

will enable any unskilled workman, or even boy, so to set them by small nuts, that the best effect may be produced. The steam ball, if once made true, wears itself and its seat true, as it turns in its bed at every stroke, so that no part of its surface falls twice in succession upon the seat.

Fig. 76 shows the "Pulsometer," as used on a private estate, pumping mud out of a lake for cleaning purposes; and Fig. 77 arranged for supplying the tenders of locomotives with water from a river.

The "Aqua Thruster" pulsating steam-pump, manufactured by Messrs. W. H. Bailey & Co., of Salford, Manchester, is illustrated in Fig. 78; sectional elevation of valve-chest Fig. 79; and section of air-valve Fig. 80. It consists of two condensing chambers, which are placed directly over the suction-valves, the delivery-valve box and valves being placed on one side of the pump. The suction-pipe is also placed in a line with the centre of the condensing chambers. A is the steam-valve chest, fitted with the vibrating flap-valve B, which has a very slight movement, and is therefore quick in its action. The valve being flat is easily surfaced, and can stand any pressure of steam, which is an advantage not possessed by the ball steam valve. A great difficulty is usually experienced on the first starting of being able to

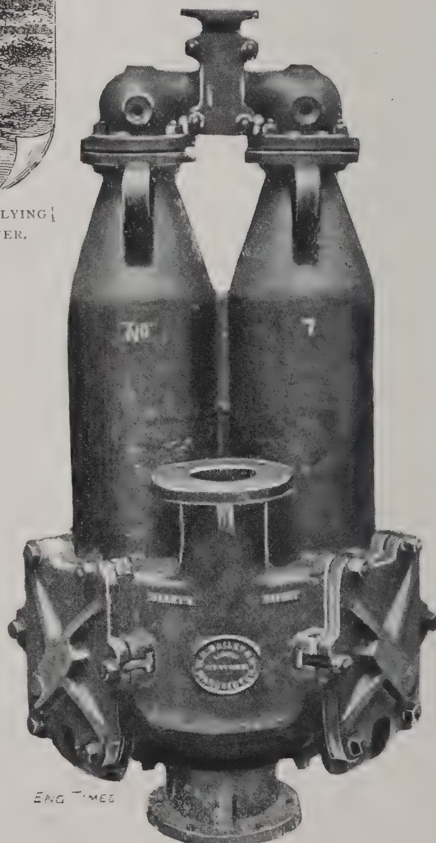


FIG. 78.—THE "AQUA THRUSTER" PULSATING STEAM PUMP, MADE BY MESSRS. W. H. BAILEY & CO., SALFORD.

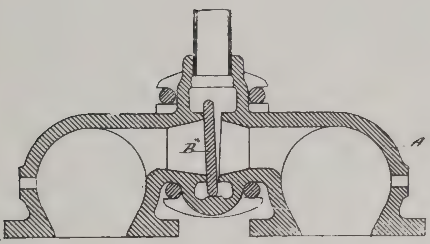


FIG. 79.—SECTIONAL ELEVATION OF VALVE-CHEST OF "AQUA THRUSTER" PULSATING STEAM-PUMP.

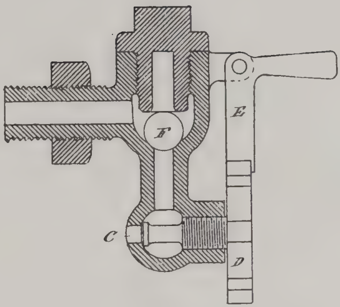


FIG. 80.—SECTION OF AIR-VALVE OF SAME.

adjust and maintain the operation of the air-valve. This difficulty has been overcome by the design of air-valve shown in Fig. 80. The inlet of air can be adjusted to varying requirements by the small valve C, which is opened by the small wheel D, which latter is prevented from turning of its own accord by means of the catch or tumbling lever E, which drops into slots provided in the circumference of the hand-wheel D. F is a small ball-valve, preventing the steam and air from returning from the condensing chambers.

The latest improvement in pulsating steam-pumps has been patented by Mr. John B. Foxwell, and is now successfully worked by the Waterspout Engineering Co., Manchester. This is illustrated by the reproduction from a photograph (Fig. 81), and enlarged sectional elevation of valve and valve-chest (Fig. 82), and enlarged end view of valve-chest (Fig. 83). The valve A is self-adjusting to its seat. It is of annular shape, with two faces parallel to each other. It is loosely supported on an oscillating saddle B, which fits into the groove C, formed between the two faces of the valve, and is embraced by the projecting arms, D and D, to prevent it rolling or moving away, and missing its faces. By this arrangement a double or duplex movement of the valve is obtained, thus enabling it to oscillate between the two valve seatings, so as to close the whole area of the steam-port at the same time, or immediately adjust itself to the seating;

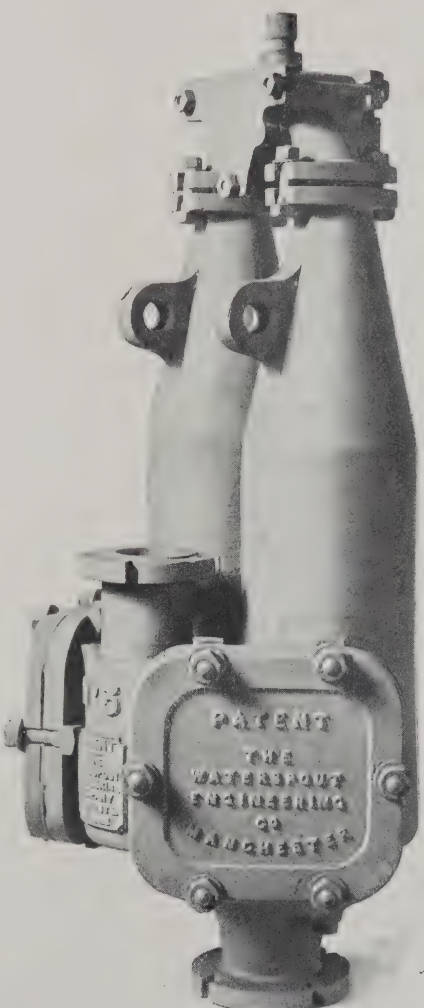


FIG. 81.—PULSATING STEAM-PUMP, BY THE WATERSPOUT ENGINEERING CO., MANCHESTER

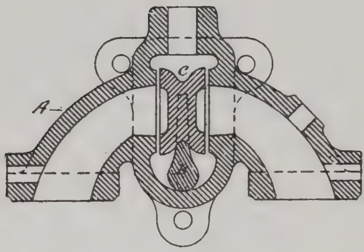


FIG. 82.—SECTIONAL ELEVATION OF VALVE AND VALVE-CHEST OF "WATERSPOUT" PULSATING STEAM-PUMP.

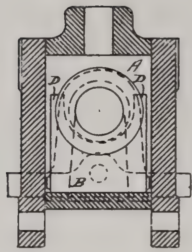


FIG. 83.—END VIEW OF VALVE CHEST OF SAME.

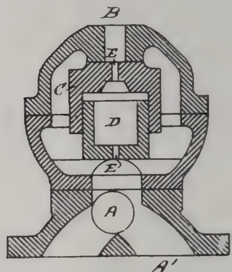


FIG. 84.—SECTIONAL ELEVATION OF "GREL" VALVE BOX AND VALVES.

also a more regular and even wear over the surface of the valve facings, and the adjustment or alteration of the position thereof to compensate for wear. The other part is almost identical with that of the "Pulsometer," so that it would only be a waste of space to give a description of it.

The "Grel" arrangement for economising the steam consumption is the outcome of a great many experiments made by the Pulsometer Engineering Company, with the view of increasing the economy of the original "Pulsometer," and at the same time retaining the simplicity of the old pump.

The "Grel" valve-box and valves are illustrated in sectional elevation (Fig. 84), in which the main steam-valve and the cut-off valve are closed. Instead of the steam being allowed to follow the water the entire length of the stroke, it is now cut off about one half the length of the stroke, and the remainder of the work performed by the expansion of the steam.

As in the ordinary "Pulsometer," there are two working chambers; the air-vessel, suction-branch, suction-valve—which is accessibie through covers—delivery-valves, and delivery-branch. It will be seen, in the illustration, that in place of the ordinary upper valve there is a special ball-valve A. This valve is the distributing valve, and corresponds to the main slide-valve used in engines having a cut-off gear. Above the valve A, but between it and the steam-pipe B, there is fitted a cut-off valve C, corresponding to the cut-off valve used in the ordinary expansion gear. This valve has its lower portion formed into a piston, which works on the cylinder D, the piston and valve being actuated by the difference of pressure within and without. The cylinder D is in connection with the steam-pipe B, and also with the space between the main and cut-off valves by means of suitable small holes, E and E.

The action of these valves is as follows: — Steam being turned on, the steam pressure will open the valve C, and flow through past the distributing valve A into one of the chambers. It enters the chamber at A1, partly driving out the water. When about half the water has been discharged, there will be, owing to the accumulation of live steam in the case D, a difference of pressure within and without the valve C, sufficient to close the valve and keep it there until the distributing valve has moved over to the other valve-seat, thus allowing the remainder of the stroke to be finished by expansion of the remaining steam in the chamber.

(To be continued.)

Philip R. Björling

HIGH SPEED TOOTHED GEARING.*

By JAMES CHRISTIE.

FOR the transmission of power it frequently becomes necessary to use toothed gearing, subjected to high peripheral speed, conjointly with high pressure per unit of tooth contact, and the object of these remarks is to record what has been successfully done in recent years, as much higher speeds are now successfully attained than formerly. Considered in a static sense, the gear tooth satisfies the condition of stress if it is proportioned to endure forces acting transversely on it, and the pressure per unit of contact is not of such intensity as permanently to deform the curved bearing surface of the teeth. When in motion, the curved surfaces slide upon each other as they enter and leave contact, and when this sliding action is accompanied with high pressure, the limit of endurance is soon reached, and in the case of inferior materials, this occurs at comparatively low speeds and pressures. In addition to this, more or less impact usually occurs, especially when the resistance is of a fluctuating character, or the loads are suddenly applied. The effects of this hammering action are discernible by a flattening of the curved faces of the teeth, after which the proper engagement of the teeth ceases and the gear is speedily destroyed.

To prevent this it is desirable to cut the teeth so accurately that no side clearance or "back lash" exists, and this is now usually done on first-class gearing of even the largest dimensions. Owing to the low elastic limit of cast-iron and the bronzes, we cannot expect these metals to endure so high a pressure as steel, and steel appears to be the most trustworthy material to endure the highest pressures and speeds. This assertion, however, does not apply to all grades of steel. Soft steel surfaces abrade or cut very readily, despite all methods of lubrication, and surfaces of this material should never be allowed to engage in sliding contact. Gearing of soft steel is usually destroyed by abrasion at quite moderate speeds. Rolling-mill pinions of steel, containing 0·3 per cent. carbon, have been destroyed in a few months, whereas the same pattern in steel of 0·6 per cent. carbon has done similar work for several years without distress. Of course, it is necessary to shape the teeth to a proper curve to insure proper engagement and uniform angular velocity.

Some years ago there was required suitable gearing to connect the engines to a rolling-mill in this vicinity. The diameters of the wheels were 37·6 in. and 56·4 in. respectively. They were intended to revolve at speeds of 150 and 100 r.p.m. and expected to transmit about 2,500 h.-p. The character of the service was such that renewal was a serious matter and long endurance very desirable. A high grade of steel was selected, especially in the pinion, in which the greatest wear would occur, and which, owing to the location, was the most difficult to replace. The

* A paper read before the Engineers' Club of Philadelphia.

pinion was forged from fluid compressed steel of the following composition :—

Carbon	0·86 per cent.
Manganese................	0·51 ,,
Silicon	0·27 ,,
Phosphorus and sulphur, both below	0·03 ,,

The spur wheel was an annealed steel casting :—

Carbon	0·47 per cent.
Manganese................	0·66 ,,
Phosphorus and sulphur, both	0·05 ,,

has been in constant operation for several years, and behaves satisfactorily.

The highest recorded speed for gearing that I can recall is that described by Mr. Geyelin in the Club "Proceedings" of June, 1894. The mortise bevels had a peripheral velocity of 3,900 feet per minute, but the pressure per inch of face was only about 680 lbs., the diameter and speed being made high to reduce the pressure on the teeth. I understand that the lifetime of these bevels is not long. If made of a grade of steel, as

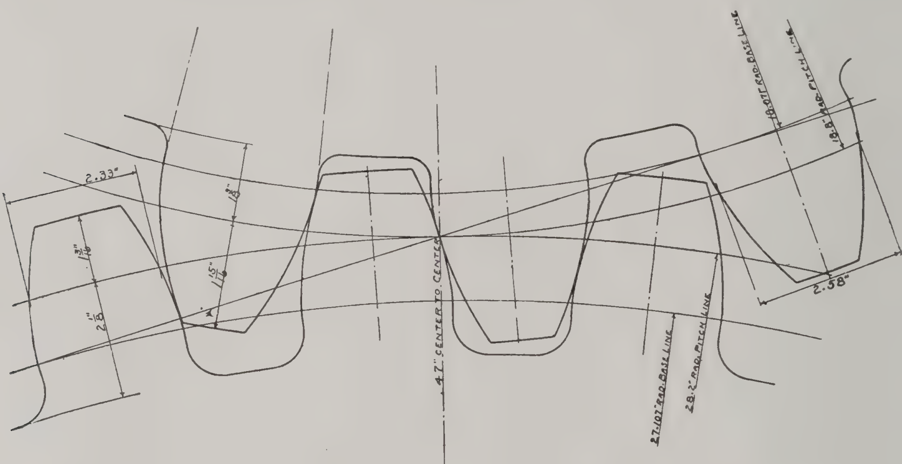


FIG. 1.

The tooth dimensions were: Pitch, 4·92 in.; face, 24 in.

These were accurately cut with involute curves generated by a rolling tangent of 16 degrees obliquity. No side clearance was allowed. After starting the mill, it was found that a higher speed was practicable than was originally contemplated. Higher pressures on the teeth were also applied, so that ultimately about 3,300 h.-p. was transmitted through the gearing, corresponding to a pressure of nearly 2,100 pounds per inch of face. The speed was variable, but occasionally attained a velocity of 260 r.p.m. for the pinion, corresponding to a peripheral velocity of 2,500 feet per minute. This gearing

previously described, their diameter and speed could be considerably reduced, and prolonged endurance would be realized.

About the same time No. 1 was installed a similar application was made to another mill, the gear having a different speed ratio, and the angular velocity being lower (see Fig. 2):

	Pinion.	*Wheel.*
Carbon......	0·90 per cent.	0·60 per cent.
Manganese ..	0·64 ,,	0·64 ,,

A much larger set had been previously employed, transmitting about 2,400 h.-p. at 750 ft. per minute peripheral speed, involving a pressure per inch of face of 3,500 pounds. This latter pair were 4 ft. and 8 ft. respectively, $7\frac{1}{2}$ in. pitch, 30 in. face, cut with

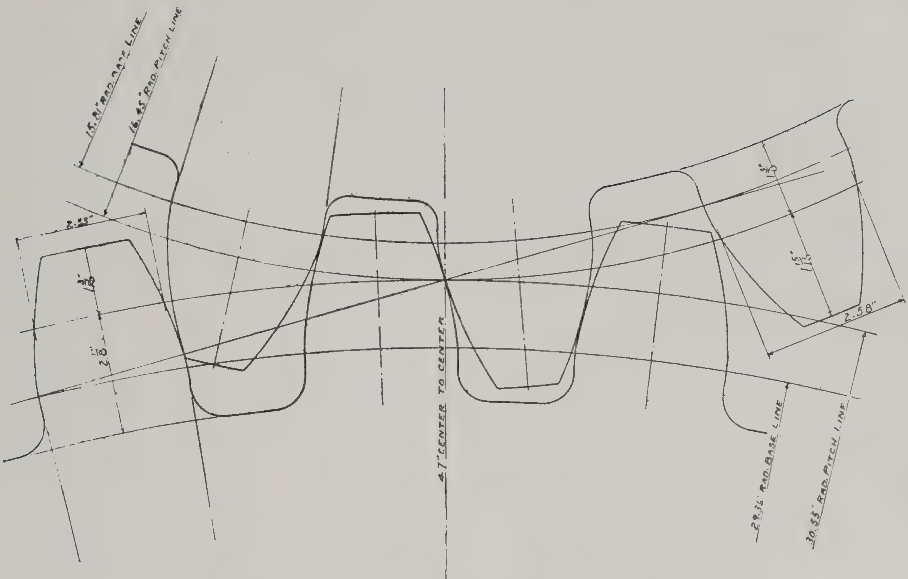


FIG. 2.

involute teeth of 14 degrees obliquity. (See Fig. 3.)

	Pinion.	*Wheel.*
Carbon	0·52	0·42
Manganese	0·55	0·73
Silicon	0·107	0·279
Phosphorus	0·022	0·078
Sulphur	0·02	0·05

These gears have all rendered excellent service, and to-day are apparently as good as at the beginning.

As considerable expense is involved in cutting large gears of hard steel, it is sometimes practicable to rough-cut the gear after it is made as soft as possible by slow cooling, a higher degree of hardening being imparted before final finishing by air hardening or rapid cooling from the refining heat. This is not infrequently done in the case of screws and gears of moderate dimensions. In this event it is desirable to have the ratio of manganese low, say not over 0·5 per cent. or 0·6 per cent.; as a high manganese content seems to impart a permanent hardness that is not readily reduced by slow cooling.

The subject of standard forms of teeth

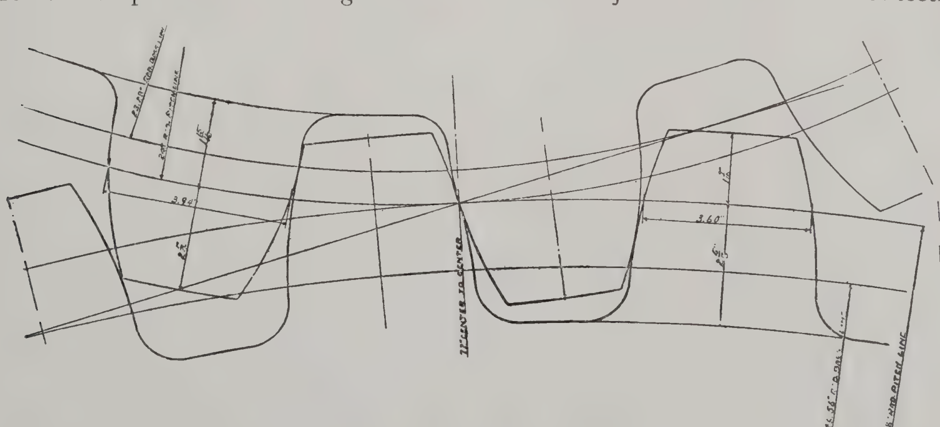


FIG. 3.

has recently become a matter of considerable interest, especially since the introduction of the electric motor, which has created a demand for accurate speed gear. Cycloidal curves so extensively used in the past seem to be less used in recent years than involute, for well-known reasons. The essential conditions required are that the osculating curves of the teeth must be normal to the point of tangency of the wheels throughout the arc of tooth engagement. Accepting the involute curve as a standard, it is desirable to adopt a uniform angle of obliquity for the generating tangent. The adoption of an angle of 15 degrees by a prominent manufacturer of cut gearing and cutters has led to an extended acceptance of this standard. It is claimed that this is not advisable, but Mr. Hawkins, who was one of the early investigators of the merits of the involute form of tooth in the middle of the century, recommended an obliquity of 20 degrees, and asserted that no practical inconvenience would be found from the resultant lateral thrust on the shaft journals.

When all other conditions are satisfactory, the flatter the curve of the tooth, the better, inasmuch as with a curve of long radius a higher pressure can be sustained than otherwise. With the ordinary straight tooth gear it is necessary to make the tooth of sufficient length, so that normal action never ceases between successive teeth. The wearing abrasion occurs when the teeth are entering and leaving normal contact. For this reason, for very high speeds some form of the stepped or spiral tooth would appear to be favourable, using a short tooth and a minute arc of engagement on the line of centres for each section of the tooth.

It appears to be practicable to maintain sliding surfaces of steel if one of the surfaces is hard, even if the other is comparatively soft; but for steel gearing for ordinary purposes I would suggest the use of steel not less than 0·4 carbon. If the speeds and pressures are unusually high, a much harder grade of steel becomes necessary. When a small pinion engages with a large wheel, the former alone can be made of high-grade steel approaching to a carbon content of 1 per cent. When extreme speeds and pressures become necessary, the best results will be found by using in both wheels steel having a carbon content approaching 1 per cent., or an equal hardness, obtained by lower carbon and high manganese or other desirable hardening addition. With gearing accurately cut from steel of this character, and securely mounted, it is believed that reasonable endurance will be obtained when the product of speed and pressure, divided by pitch, each within certain limits, does not exceed 1,000,000: for example, a speed of 3,000 ft. per minute and 1,600 lbs. pressure per inch of face, or *vice versa;* for gear of 5 in. pitch, assuming, so far as we know, a maximum speed of 5,000 ft. per minute for gear of any pitch, and permissible pressure to be proportional to the pitch.

This statement that speeds and pressures are reciprocal, or as one is increased the other must be reduced, in a fixed ratio, may not strictly be a rational one, but in a broad and general sense it is correct within the usual limits of practice.

It will be understood that such a generalization as herein stated would apply to pinions having a liberal and not the minimum number of teeth.

THE USE OF COAL-DUST FOR STEAM-RAISING PURPOSES.

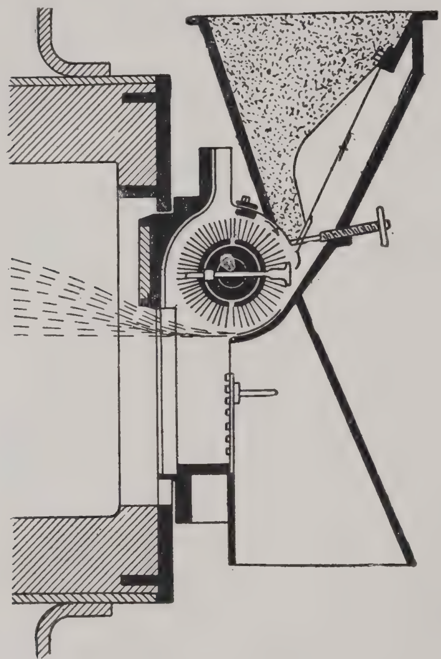
LITTLE attention seems to have been paid in this country to the use of coal-dust for steam-raising purposes. In Switzerland and America experiments have been systematically prosecuted for some considerable time, and though it is difficult to ascertain what definite results have been produced, still it is known that very satisfactory progress has been made. If an apparatus could be devised and conditions evolved for economically burning pulverized coal, a big future would undoubtedly be open to this kind of fuel. Even at the present time with dust-burning processes, there is an absence of smoke, and also, comparatively speaking, of cinder and ash residues. Another distinct advantage is that not only can a lower grade of coal be utilised, but mine screenings can also be made use of. Furthermore, it has already been seen in experiments that the feed of furnaces with dust can be more automatically regulated, thus dispensing more completely with the unsatisfactory personal equation. It is considered that advantages such as these more than repay the cost of pulverizing.

Before successful results can be obtained, the coal must be reduced to a uniformly fine powder, and boilers must, of course, be specially adapted for dust burning. When dust is being fed, the fire-box shows simply a big column of flame similar to that produced by oil feeding. In some experiments the grates have been bricked over, and form simply a hearth; and the endeavour is to get as long a flame way as possible. The methods adopted to feed dust into the furnace automatically and to the best advantage are varied, but the majority assimilate the form used in feeding oil into a furnace, some inventors using compressed air, and others revolving wire brushes and such arrangements for distributing the fuel.

In 1896 experiments were made at the Berne Small Arms Factory, under the superintendence of the Swiss Society of Boiler Owners. The boiler used was of the Sulzer-Cornish form, and the "Mehl" grate and Wegener system of firing were both tried. The results appeared in the 1896 report of the Society, and showed that the dust could be burnt smokelessly with a thermal efficiency of 20·93 per cent., and a saving in cost of steam of 15·5 per cent. Subsequently, at the Gelafingen ironworks, a Lancashire type of boiler was fitted up for coal-dust burning, and since the spring of 1897 Messrs. Sulzer have given the subject great attention. In Basle the Warteck Brewery took up the subject, and used the Wegener apparatus, and comparative tests were made with this and the "Cario" system of firing, and proved favourable to the former.

The Illinois Central Railway Company of America have for some time past been experimenting with apparatus for burning bituminous coal in a pulverized state. The apparatus used is shown

in our illustration,* and is placed on a 125 h.-p. water-tube boiler. It is mounted on a framework, which is hung

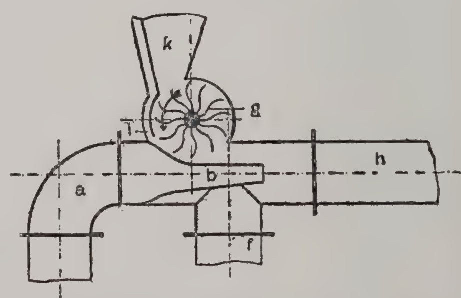


REVOLVING WIRE BRUSH COAL-DUST FEEDING APPARATUS.

to hinges on the square opening of the furnace front, just as is the ordinary swinging fire-door which it replaces. The apparatus can thus be swung open, out of the way, if desired. An overhead small line shaft is run from a small upright engine, and a belt from a pulley on this line shaft connects with a pulley on the end of the cylindrical wire brush seen in the illustration. The brush is about 18 in. long by 6 in. in diameter, and is revolved at a speed of about 800 revolutions a minute. Above the brush is a hopper, which is kept filled with ordinary Illinois bituminous coal pulverized to a flour-like consistency. The mouth of the hopper is closed with a sheet of metal immediately above the brush. This sheet can be sprung to or from the mouth by means of the set screw, thereby regulating the flow of the dust down on to the brush. The front or longitudinal side of the hopper is formed of a steel plate strengthened by a straight spring. At the lower edge of this slide is a projection, which is struck at each revolution of the brush by an excentric, which takes the place of the striker shown. The sheet side of the hopper is thus kept agitated to cause the dust to drop freely through the mouth slit on to the brush.

As the fuel drops on the brush it is carried down and swept on into the fire-box in a sheet-like stream in the manner indicated by the broken lines. By the time this sheet of dust has proceeded a foot into the furnace the particles become ignited, and each particle being so small that the air has ready access to it, bursts into a flame which is drawn along by a very moderate draft.

Another apparatus has been introduced by H. Buderus Hirzenhain, which distributes pulverulent fuel by means of compressed air. The object of this arrangement is to secure an intimate mixture of fuel and air before the fuel is forced by the air issuing from the



APPARATUS FOR DISTRIBUTING COAL-DUST BY COMPRESSED AIR.

compressed air-pipe or nozzle into the combustion chamber, and prior to the admission of a further supply of air. This apparatus will be more readily understood by reference to the illustration, by which it will be seen that the

* From *The Railway and Engineering Review.*

fuel, in a finely divided condition, is driven downwards from the hopper *k* by a wheel *g* provided with vanes. At the back of the hopper *k* is a channel *i*, which communicates with the atmosphere, and the lower end of which opens into the air blast chamber tangentially to the wheel *g*. Compressed air is supplied through the pipe *a* and nozzle *b*, and, by its injector action, draws air down the channel *i*, and causes it to mix very thoroughly with the fuel. The mixed air and fuel then get a further supply of air from the nozzle *b*, and the whole is forced along the pipe *h* into the combustion chamber of the furnace. Hot air may be drawn up the pipe *f* to join the mixture.

We shall be glad to hear from any of our readers who have had any practical experience with the burning of coal-dust for steam-raising purposes.

"E.T." OFFICES.

DYNAMO ILLS AND REMEDIES.*

A DYNAMO or motor, carefully installed and properly running, is truly a thing of beauty to those who have the care of it, and a source of satisfaction to its owner. Trouble, however, in one form or another is sure to come sooner or later, depending on the grade of the machine and the skill and care in handling.

It is therefore likely that a few hints, as to the cause and remedy of such troubles, will be acceptable to those who have the care of this class of machinery.

Obviously, the promptness with which such troubles are located and removed will have much to do with the success of the plant. Often, indeed, considerable expense is incurred in removing a fault, which with a little intelligence could have been remedied at trifling cost.

For instance, so slight a thing as a loose connection will often cause the shutting down of a whole factory with scores of hands. Other troubles equally as simple, but not so easily located, will cause annoyance and delay. In such cases, some knowledge on the part of the man in charge in locating troubles would have enabled him to overcome the difficulty, and save delays and consequent loss.

Fortunate it is that the machines in question are mechanically so simple in their construction. With the exception of commutator and brushes, there are but two wearing parts: the two bearings which support the shaft of the armature. Quite in contrast in its simplicity to the steam engine, with its multiplicity of wearing parts, oil cups, and valves.

From the fact that the dynamo or motor has so few parts, we are able to classify their troubles through their effects, under five heads, which are :—

1. Sparking at commutator.
2. Heating of the various parts.
3. Noise and speed.
4. Motor stops or fails to start.
5. Dynamo fails to generate.

Any and all of these effects are quite obvious, even to a casual observer; still a most careful and thorough examination should be made of the entire machine, in order to be sure of facts, and to avoid jumping at conclusions.

In the consideration of troubles as classified above the following order will be observed: 1st, the cause; 2nd, the symptom in detail; 3rd, the remedy, and how effected.

As is very often the case, a symptom may be developed in a machine from several causes, or a cause may result in several symptoms. We shall, however, endeavour to make the distinction as clear as is possible without the help of the actual machine for illustration.

Sparking at the commutator is caused, first, by the armature carrying too much current, due usually to an overload; in the case of the dynamo, too many lamps in circuit; or in the case with the motor, excessive frictional load, from hot bearings, armature striking the pole pieces, belt too tight, or, in general, too much mechanical work to be done. Excessive voltage on constant

* Reproduced from the *National Engineer.*

potential circuits will also overload the system.

The symptoms are a continuous sparking at the commutator during the times of maximum load, and tendency to slipping of the belt.

After a continuous run, the armature becomes very much overheated, and will burn out if the load is not lightened.

In this, however, there is an exception, constant current arc motors. As

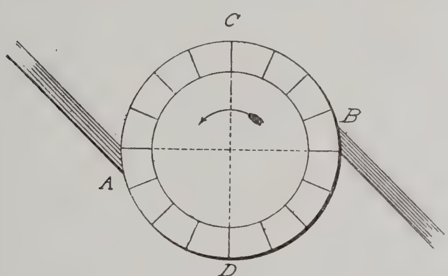


FIG. I.—THE DIAMETER OF COMMUTATION.

the heating effect depends on the square of the current multiplied by the resistance (C_2R), both of which factors are constant in this instance, it is quite possible to overload machines of this type till the armature stops without risk of burning it out.

Excessive friction load is readily detected by turning the armature around by hand.

Hot bearings will be treated more in detail under the head of heating of the various parts.

An excess in current is, of course, at once evident at the ammeter, and this may be taken as a conclusive test for all such overloads.

The remedy for troubles of this nature is obviously to reduce the load, and eliminate partial short circuits in the line and leaks as far as possible.

Constant potential motors, especially those above five horse-power, are frequently subjected to overloads and strain at starting.

If the starting box has too little resistance, or is turned on too rapidly, it will cause the armature to start with a jerk, and spark badly at first. A properly designed starting box will remedy the evil in the first instance ; and in the latter case, the exercise of proper care in starting. The handle of the starter should be allowed to remain an instant on the first and second contact points till the armature has attained some speed.

Again, brushes are sometimes not set at neutral points. The symptom of this trouble will be a sparking and cutting at the commutator, the intensity of which will vary with the shifting of the brushes.

The remedy can best be explained by referring to Fig. 1, which shows the proper position of the brushes. The points where the brushes are resting on the commutator where the greatest E. M. F. and the least sparking are obtained, are called the neutral points, as represented in the cut by the points "A" and "B."

The line joining these two points has been termed the diameter of commutation. It will be noted that this line is

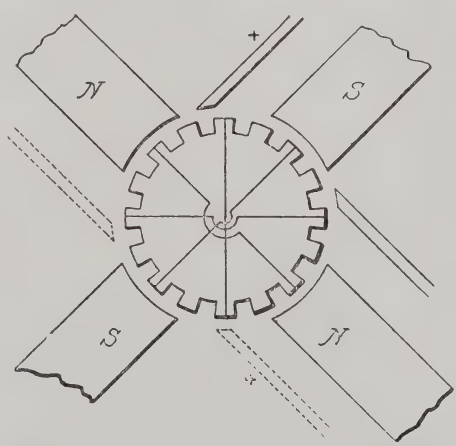


FIG. 2.—CIRCUITS OF CROSS-CONNECTED ARMATURE. FOUR POLES, TWO BRUSHES.

not at right angles to the line joining the centres of the pole pieces, but is shifted through a small angle, depending on the direction of rotation and whether the machine is acting as a dynamo or motor.

With the dynamo, the brushes will be given a forward lead, that is, they will be shifted from the horizontal in the direction of rotation.

With the motor, the shifting of the brushes will be against the direction of rotation, and will be given what is termed a backward lead.

In most dynamos and motors the exact position of the neutral points cannot be fixed, but will vary according to the load of the machine. For instance, in the case of a dynamo with a given number of lights burning, the brushes may be properly set at the neutral points and running without sparking. Now let the number of lights burning be increased or diminished to any considerable extent and sparking, more or less destructive, will commence and continue till the brushes have been shifted to the new neutral points by means of the rocker arm. These points are determined only by trial.

This shifting of brushes, or giving them a lead, as it is called, is necessitated by armature reaction or the magnetizing effect of the current in the armature, tending to create a powerful magnetism, which distorts the field.

Right here we will state that there are some dynamos and many motors in which it is not necessary to shift the brushes, no matter how much the load changes. In these the field has been made strong enough to overpower the armature reaction. Again, in another class of dynamo, the moving of the points of contact is taken advantage of as a method of increasing or decreasing the E. M. F. This is the case of constant current arc machines.

It is not only necessary to shift the brushes to the neutral points by means of the rocker arm, but care should be taken to see that the brushes are diagonally opposite each other. This can be accomplished by counting the number of segments of the commutator, measuring with a piece of thread or other device, marking the opposite segments, and setting the brushes to this mark.

The setting of brushes is perhaps the most important duty of the dynamo tender, for a brush, a fraction of a segment out of position, will often cause serious sparking.

Exceptions to the rule for setting brushes diametrically opposite will appear in the case of multi-polar motors with cross connected armatures.

These machines may be supplied with two sets of brushes, or as many sets as there are poles. For instance, four pole machines with two sets of brushes require them to be set at 90° apart; six pole at 60° or 180°, and so on.

Fig. 2 shows the armature connection and the position of the brushes in a four pole machine with cross connected armature. The arrows mark the direction of the current in the armature connection. It is apparent, therefore, that no one should attempt to set the brushes on such a machine without first determining from a blue print or other source their correct position, and then keeping them there.

Should the brushes be set very far out, they will probably cause the safety fuse to blow; and in the case of a dynamo it will fail to generate.

The commutator may have high bars or low bars, due to loose shell or an unusually hard specimen of copper.

A poor connection between the leads and the tongue of the commutator segment will also develop a flat, hard mica between the segments, which does not wear down as fast as the copper: all of these produce a rough commutator.

The symptom in this case will be a chattering of the brushes, accompanied by sparking, which is sometimes apparent by the sound. By touching the commutator with the top of the finger, the least roughness is at once apparent.

Turn the armature slowly by hand, when any eccentricity will be indicated by a rise and fall of the brushes.

The commutator as it should be is represented in Fig. 3, with brushes properly set and the surface of the commutator smooth and glossy.

Accompanying is a sketch of the same commutator in bad condition, the commutator being scarred and rigid, and the brushes badly set.

In cases where the commutator exhibits eccentricity or is deeply cut, the armature should be taken out, accurately centred in a lathe, and the commutator turned off, taking off as light a chip as possible.

In large armatures it is often more convenient to rig up a special slide rest and turn off the commutator, while the armature is turned at slow speed in its own bearings.

A loose bearing will also cause chattering of the brushes, with the attendant sparking and cutting of the commutator. If the bearings are loose

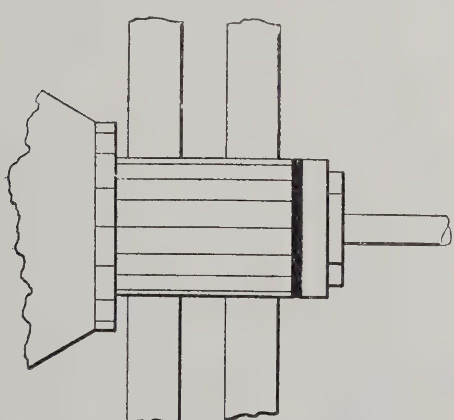


FIG. 3.—COMMUTATOR IN GOOD CONDITION.

and worn they should be re-babbitted, or new ones put in.

A slide rest which clamps on to the pillow block in place of the rocker arm is shown in Fig. 6.

A slightly rough commutator can be dressed down with a fine file and given a final application of fine sand paper, the armature being turned at medium speed.

If the machine in question is a dynamo it is advisable to raise the

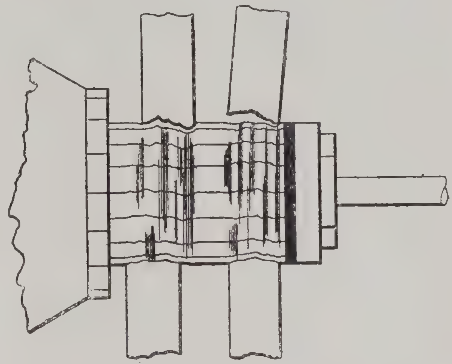


FIG. 4.—COMMUTATOR IN BAD CONDITION.

brushes, start the engine at medium speed, and apply the file or sand paper, or both, as the case may be, thus avoiding clogging the brushes with dirt and copper dust.

With a motor it is different, as we must rely on the current to turn the armature. It is, therefore, an exceedingly dangerous practice to use a file, although sand paper may be applied without danger. It is a good plan to put a little oil on the sand paper, for in this way the particles of copper are gathered and prevented from flying into the armature, thus increasing the danger of short circuits or burn outs.

It may be stated as an axiom that copper dust and metal filings in general should not be allowed to collect about a dynamo or motor. For this reason emery cloth should never be used on the commutator, as the particles of emery are so sharp they become lodged in the copper of the segments, thus converting the commutator into a veritable grinding tool. Again, the particles get into the mica, and cause short circuits.

Brush-holder screws sometimes become loose, and the brushes get tipped up, so they touch only at one point.

Very often vaseline or oil has been applied too freely, and the commutator has become dirty. The springs which give tension to the brushes may have lost their temper from carrying the current, though this is an indication of a faulty design of brush-holder. The bearing part may have been clogged for some reason, so that the holder does not work freely—though the spring may still be good. Hard carbons that will not adjust themselves in wearing to the commutator, and which sometimes offer exceedingly high resistance, also induce sparking at the commutator.

Copper brushes can best be filed for adjustment to the commutator in a jig made for the purpose.

The simplest way to adjust carbon brushes is to first wrap a piece of sand paper around the commutator, having the rough side of the paper turned out ; then set the carbon brushes down tightly against this surface, revolving the armature by hand, while the brushes will be rapidly and accurately shaped to the surface.

The best way to keep a commutator clean is to wipe it at intervals with a piece of cotton cloth or felt slightly moistened in vaseline.

A motor with short circuited coils or bad grounds will draw excessive current, even though running free of load. A dynamo will require considerable power, though there is no evidence of power in external circuit. In either case violent sparking will result.

The symptoms most apparent will be a heating of the coil or coils affected, and the attendant will become warned of the danger by the odour of the burnt cotton insulation.

A short circuited armature coil often results from allowing copper dust to collect back of the commutator, or when excessive sparking of the brushes has formed little bridges of metal across adjacent commutator segments.

Short circuits in parts of the coils of an armature frequently occur from injuries to the insulation, from external mechanical sources—for instance, the dropping of little particles of material in the spaces between the armature and pole pieces while the armature is in motion. A screw, for instance, or even little balls of waste, and more frequently oil and dirt, cake on the faces of the pole pieces, scraping the insulation off the wire.

A piece of iron, a screwdriver or key, for instance, held between the field magnet, near the revolving armature, will vibrate very perceptibly as a short circuited coil passes.

In the case of a motor, an armature affected with a short circuited coil will revolve slower than usual and unsteadily, while in aggravated cases it will draw up with a jerk before the pole piece.

Ills such as those described as short circuits due to deposits of copper dust back of the commutator or the bridging over of segments from sparking, may be located by careful inspection, and removed by scraping clean the mica insulation between the segments.

Short circuits, due to mechanical injury to the insulation of the wire of the armature, require careful handling, as these injuries generally extend before the first layer of wire.

In most cases it is possible to carefully lift the wires, one at a time, high enough to wrap it with silk tape.

Wires thus raised and insulated must be carefully pounded back into place with a wood block or mallet, the affected part being then treated with a coating of good shellac.

A short circuit which is in the coil itself and below the surface cannot be treated thus, and the only real remedy is to rewind the coil.

Two or more grounds in an armature, occurring usually from insufficient insulation on the core, are equivalent to a

short circuit, and must be treated in the same way, viz.: by reinsulating and rewinding the armature.

The commutator will flash violently when the broken coil passes under the brush, and it will be found that the mica surrounding the segments attached to the broken coil will be blackened and burnt and gradually pecked away.

This break will often be found in the leads where the armature wires connect with the commutator, as in some types of machine they are subject to heavy drag. Usually they can be easily repaired by splicing.

An overload may cause the soldered connection of the leads to the commutator to melt, and thus develop a break. The only available remedy is to solder in the leads again, and guard against overload in the future.

Care must be exercised in the soldering process, lest drops of molten solder drop in behind the commutator, and short circuit some of the segments.

When the trouble cannot be so easily located, and is evidently in the interior of the coil, the coil thus affected will have to be rewound.

The trouble, however, may be temporarily remedied by cutting out the coil,

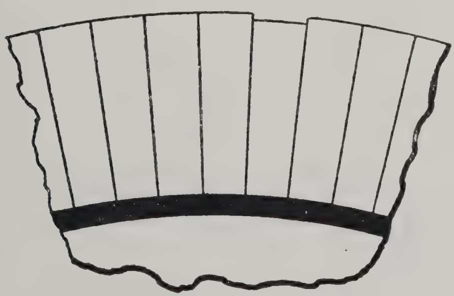


FIG. 5.—A LOW BAR.

either by bridging over the disconnected segment with a drop of solder or by staggering the brushes, as it is called; that is, setting one of a pair a little ahead and the other a little back of their normal positions, which is equivalent to bridging over the break.

In adopting this method, care must be taken not to short circuit a sound coil, as this will cause sparking, and a dangerous heating of the affected coil.

These devices are at best only "make-shifts," and should only be adopted to prevent a very undesirable stoppage.

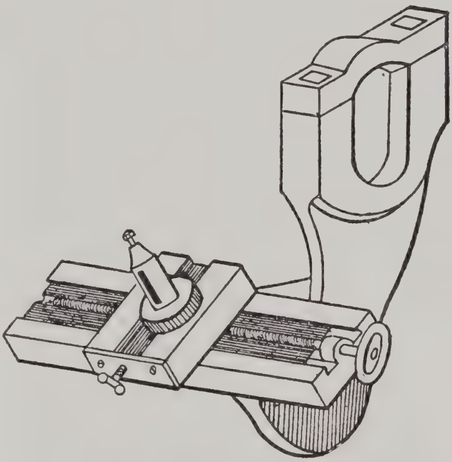


FIG. 6.—A TOOL CLAMPING ON PILLOW-BLOCK, USED TO TURN OFF COMMUTATORS.

Field troubles cause sparking at the brushes, and are of two kinds, open circuits and short circuits.

A dynamo thus afflicted does not generate at all, or does not come up to its full electromotive force. The pole pieces are not strongly magnetic.

A constant potential motor has a tendency to race unless the field is very weak or is lacking altogether, in which case it may either run slow, or stop and blow the fuse.

The cause for such trouble is usually a broken circuit or a partial short circuit in one or both of the fields.

In order to test for an open circuit in the field of a motor, block the brushes up from the commutator with pieces of wood or paper, then turn on the current, remove the field wire from its binding post, and absence of spark at the

breaking of the circuit will indicate a complete break somewhere in the circuit.

In cases of field trouble in isolated dynamos where current is not obtainable, it will be necessary to remove the terminals of the field circuit from their binding post, and ring through it with a magneto or bell and battery.

Short circuits in field coils may be determined by measuring, with the proper instruments, usually a portable bridge and galvanometer, the resistance in each magnet coil. Any appreciable difference in the resistance of the magnets will indicate that the one of least resistance has been short circuited.

A machine thus affected will spark more at one brush than at the other when running, and it will further be noticed that the short circuited magnet will heat less than the sound one, which, in turn, will be above the normal.

The remedy for such troubles is to remove the faulty magnet and unwind the wire on it till the break or ground is found, when the fault may be repaired, and the wire wound back again.

It may be stated here that a frequent cause of short circuits in field magnets and armature is due to the soaking they receive from oil thrown out by faulty bearings.

Oil, soaking into a field, seems to have the effect of rotting the insulation on the wire, and a short circuit or ground is the result.

A carbon brush of high resistance may cause sparking because of its poor contact with the commutator. A charring or burning of the brush about the edges will be noticed, and the brush itself becomes hot, in which case supply a softer brush.

Again, vibration in the machine, due to insufficient foundation, is frequently a cause of sparking. It will be found to decrease when the machine is braced. Often nothing more is needed than a slight increase in the tension of the brushes. The better way, however, is to secure the machine firmly to a good substantial foundation of masonry.

A chattering of the brushes is sometimes due to a dirty and sticky condition of the commutator. This is apt to be the case with radial carbon brushes. To remedy this, wipe the commutator clean, and then lubricate it with oil or vaseline rubbed on with a piece of cotton cloth or felt.

A trouble to which the same armatures are liable, and which is sometimes very difficult to locate, is what is termed a flying break.

This will develop after the armature is in motion, causing violent sparking, with every indication of an open circuit, but will not be apparent to tests made when the armature is stationary. It can usually be found by careful inspection of the back, and can be repaired with thoroughly good soldered joints.

LIFTING ELECTROMAGNETS.*

By E. B. CLARK.

(*Continued from p.* 110.)

THE accompanying engravings illustrate the facts emphasized in the general discussion presented in the preceding article (Vol. V., No. 2, p. 105). Fig. 5 shows a section through a magnet built on the principle of a modified horseshoe, having one pair of concentric poles. The horns on the sides are for the purpose of attaching sling chains in case of the disablement of the magnet. Fig. 6 shows a perspective of the same magnet. Though at first glance this seems to be an admirable design, as a matter of fact it was a failure in practical operation. It has the advantage of thorough protection of the winding from external injury, which is important, but it possesses the following disadvantages :—

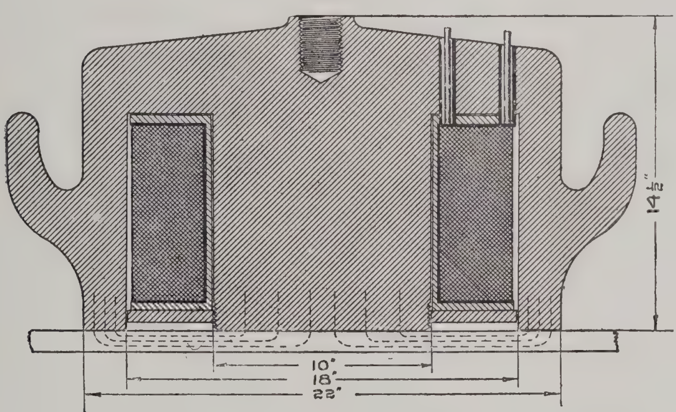


FIG. 5.—CROSS SECTION OF ROUND MAGNET.

(1) Large size, and therefore low ratio of lifting power to weight. (2) A circular form of pole face, which is poorly adapted to hold a flexible piece such as a steel plate, for a long plate bends down at the ends and strips off from a round pole face. (3) Absolutely no ventilation of the winding. All heat loss in the coil must be dissipated through the outside pole or shell by conduction, and thence to the atmosphere by radiation. The winding must, therefore, be heavy to prevent over-heating. (4) High leakage, due to the short distance between poles. (5) High cost of construction. (6) Necessity to take magnet apart in order to repair a broken terminal lead (the fracture in which always occurs close to or inside of the magnet).

Notwithstanding these objections, the performance of this magnet, when tested, looked excellent, on paper. It lifted over 12 tons with 13 amperes at 250 volts, or 3,250 watts. Its weight was 1,235 lb., giving a ratio of weight lifted to weight of magnet of about 19.

At this point it might be pertinent to note that the lifting power of a magnet obtained in a test where every condition is advantageous to high tractive effort, means absolutely nothing from a

* From the *American Electrician*.

FIG. 6.—EXTERIOR OF A ROUND MAGNET.

practical standpoint. The winding of any magnet can be so proportioned that a keeper laid across its poles cannot be detached by a pull of less than 130 to 150 lb. per square inch of pole face, provided the air gap be made small and the keeper be thick enough to carry the magnetic flux. The round magnet described above is an example of high lifting power, but small practical value.

Fig. 7 shows a section through the poles and windings of a bipolar magnet in use by the Illinois Steel Company for a number of years for handling plates. Fig. 8 shows a side elevation, and Fig. 9 a perspective view of the same magnet. The form of the pole face is well adapted to plate handling; when it is laid across the plate a long surface of polar face is presented to resist the first tearing-off tendency, due to the plate bending down at the ends. The pole faces being some distance apart do not encourage leakage. The magnet will pick up several plates at a time, which is an advantage when loading small sheared plates and a disadvantage when handling long unsheared plates. This magnet, however, as did the round magnet, possesses the disadvantages of large size, lack of ventilation, high first cost, and high cost of maintenance. It must be taken apart to repair a lead broken close to the frame, or to replace a worn eyebolt. The top plate is of steel, the pole pieces are of wrought iron, the casing is of cast brass, and the winding of No. 14 double cotton-covered magnet wire (two coils, 85 lb. each). On test it has lifted 6 tons with $6\frac{1}{4}$ amperes, at 250 volts, or 1,562 watts. Its weight is 1,200 lb., giving a ratio of lifting power to weight of 10.

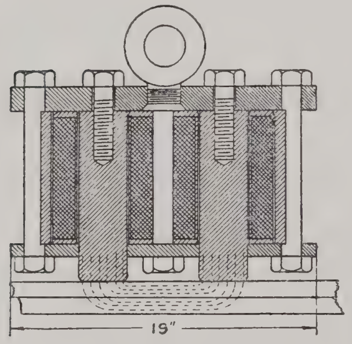


FIG. 7.—SECTION OF BIPOLAR MAGNET.

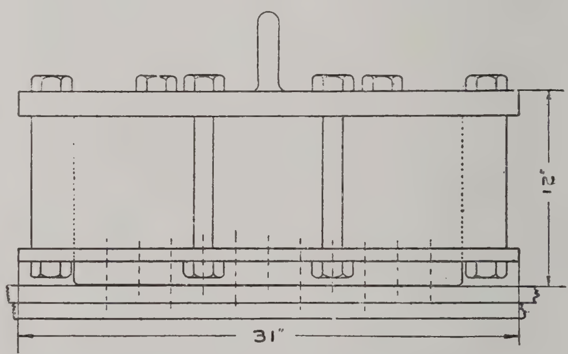


FIG. 8.—SIDE VIEW OF BIPOLAR MAGNET.

A comparison of the data given for

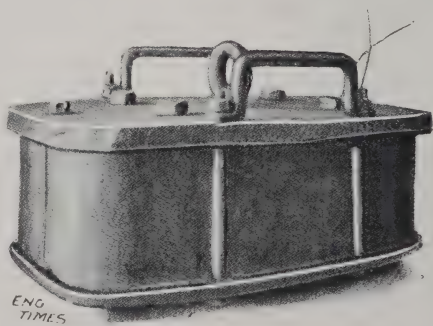


FIG. 9.—EXTERIOR OF A BIPOLAR MAGNET.

these two magnets makes it appear that the round magnet is much better, but, as already stated, the round one was a failure and the long one a success. The conclusion is that the figures usually given for the performance of a magnet, viz., lifting capacity and power consumption, are absolutely valueless from a practical standpoint. The coil of the round magnet has 2,904 turns of wire weighing about 217 lb.; the two coils of the long magnet contain 2,952 turns and weigh about 176 lb. The round magnet, with its compact design, can lift more than twice the load of the long one because of its greater number of ampere turns; yet it was a failure by reason of its shape. The lesson taught is that the shape must be right, the design compact, and the magnet small. With these points in view, the solution seems very simple. It merely consists in properly grouping small magnets into one complete and mechanically well-designed structure.

The writer, after considerable experimenting about two years ago, selected, as the best shape and best size of unit for handling plates, a pole piece having a cross-section of 1 in. by 5 in., and a length of 3½ in. Its coils surrounded it to a depth of ¾ in. (including insulation), and covered 2¾ in. of the length of the pole piece. No bobbin was used, the insulation of the coil being sufficient to protect it. The pole pieces were cut from 1 in. by 5 in. bar iron or soft steel and planed to true surfaces top and bottom, in groups of eight or ten at once. When the corners were rounded with a file, and the pole piece drilled and tapped for ½ in. bolts, it was finished. The coils were all alike, being machine wound and interchangeable. In the light of more recent experience this design evidently could be improved, but it is doing and has done for two years, most successful service. Its small size (requiring small head-room) and its low weight were particularly advantageous in this case.

Fig. 10 shows the side elevation of a magnet built up in this way. Fig. 11 is an end elevation, and Fig. 12 a perspective of the same magnet. In this case the service was the handling of long unsheared plates, several magnets being hung from a long beam and operated simultaneously. It is desirable to take a very firm hold on one plate without picking up the floor plates of the "hot-bed." With this object in view, the twelve poles are arranged in two rows of six each, alternating in polarity. The magnetic flux then passes each way from each pole, the result being to reduce the reluctance of each circuit to less than it would be even if used as an independent magnet, and also to avoid carrying the density of magnetization in the plate being handled to an excessive point. The plate, therefore, short circuits the lines of force and prevents the leakage through to the lower side, which would pick up the floor plates. A large area of plate surface is covered and a powerful grip taken on that area.

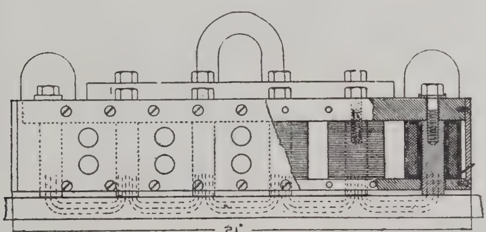


FIG. 10.—A MULTIPOLAR LIFTING MAGNET.

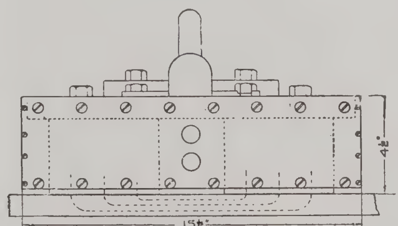


FIG. 11.—END VIEW OF MULTIPOLAR LIFTING MAGNET.

The general form of the magnet face is rectangular, which is the shape best adapted to prevent stripping off. The top is one continuous piece of dead soft-steel plate, finished on the bottom and edges. Tap bolts hold the pole pieces to this plate. Above this is an eye-plate, into which the eye for supporting the magnet is riveted. By this means a worn eye can be replaced quickly and easily without disturbing the magnet proper. The terminal leads are so arranged that they cannot be broken inside of the top plate, being connected externally to terminals which are protected by cast-brass guards, easily removable. Details of this terminal are shown in Fig. 13. The coils are held in position by a bottom plate of cast or sheet brass, which, in turn, is held by side plates of sheet brass; these also afford protection to the sides of the coils. Ventilating holes allow free circulation of air through the interior. In a very wet place these holes could be omitted, but no trouble has been experienced from weather grounds where good insulation is used. The magnet weighs, complete, 300 lb., and lifted, in a test similar to those given the bipolar magnets previously mentioned, 4 tons, making the ratio of lifting power to weight about 27. It takes 4·4 amperes at 250 volts (1,100 watts), but it works with 4 amperes at 230 volts (920 watts).

However, as previously stated, these figures really tell nothing of the value of a magnet for actual use. As a matter of fact, the most powerful magnet thus far described, the round type, was absolutely useless as a plate handler; the next one, also powerful, was partly satisfactory; and this least powerful one is the best in this particular case. It weighs about one-fourth as much, uses about two-thirds the power, costs about one-half as much, requires almost no repair, and holds a plate far more securely. The weight lifted per watt expended is not large, but a large figure for this ratio does not necessarily indicate a good design. In ordinary plate handling, a large air gap must be taken into consideration, which means that a large flux must be driven through a high reluctance. If this air gap be reduced to make a big lift on test, the winding will take just as much current, but the flux will not be as much per watt expended because of the decreased permeability at the high density of magnetization in the pole piece, which is above saturation. If it is desired to build a magnet which will show a big lift per watt expended, on a test, the winding should be so proportioned that the poles are not over-saturated, and a

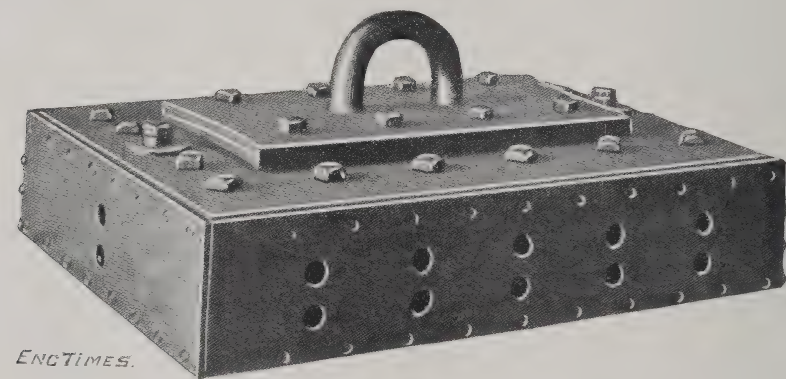


FIG. 12.—PERSPECTIVE VIEW OF MULTIPOLAR MAGNET.

large area of pole faces should be allowed. But when such a magnet is placed in use where a big air gap is unavoidable, it will suffer a severe impairment of lifting power because of the increased reluctance and consequent decreased magnetization.

To secure this high ratio of lifting power to watt expended, the current density in the coils should also be made very low; that is, a large number of turns of wire should be wound on, which will decrease the current without decreasing the ampere-turns. Of course, though, this will increase the weight of the magnet, both as to iron and copper, and will run its cost up.

In handling sheared plates it is frequently desirable to expedite the work by picking up several small plates at once. If they are very small, say only a couple of feet square, they can be handled on edge, but if larger, they have to be picked up flat, one on top of another. A magnet for this work is built up in the same manner, but the poles are arranged differently. Fig. 14 shows a side elevation and Fig. 15 an end elevation of such a magnet. The poles are arranged in four rows of three, each placed end to end. The first and second rows are close together and the third and fourth rows are similarly arranged, but considerable distance is left between the second and third rows. All poles on one side of this space are of one polarity, and all on the other side are of the opposite polarity. Then all the flux must pass over the space between the second and third rows. A plate across the magnet face then becomes saturated, and some flux is

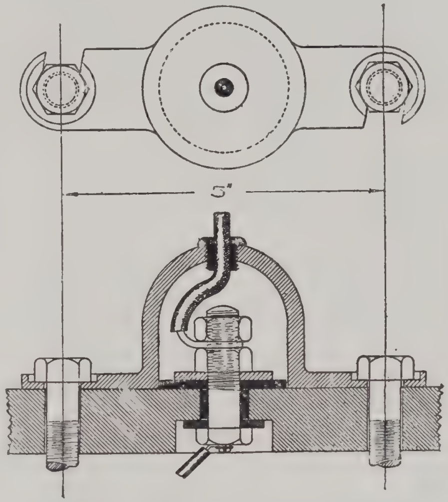


FIG. 13.—DETAIL OF COIL TERMINAL.

forced down into the plates below. The result is that several plates are picked up. By connecting the coils in two circuits and bringing the leads out to suitable pole-changing devices, which can be made very simply, the arrangement of polarities here described can easily be changed to the more economical one first described, for ordinary work, in which it is not desired to handle more than one plate. In the case of each magnet illustrated, a plate is shown across the magnet face, and dotted lines are drawn, showing the path of the magnetic flux through the lifted plate.

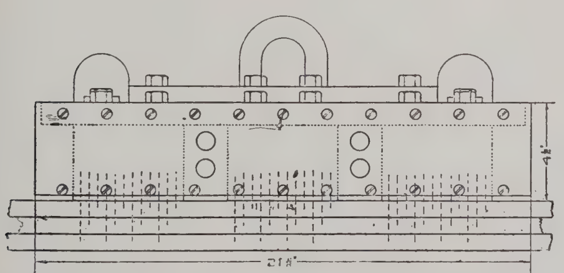


FIG. 14.—MULTIPOLAR MAGNET FOR LIFTING SEVERAL PLATES AT ONCE.

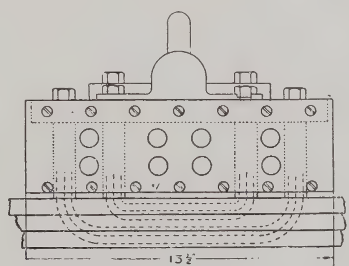


FIG. 15.—END ELEVATION OF SAME.

DATA FOR THE DESIGNS ILLUSTRATED.

Type of magnet	Round, Fig. 6.	Long, Fig. 9.	Small, Fig. 12.
Size of wire	No. 12.	No. 14.	No. 17.
Turns per coil	2,904	1,476	644
Total turns	2,904	2,952	7,728
Total pounds of wire	217	176	57
Total resistance at 50° C.	19·25 ohms.	40 ohms.	56·6 ohms.
Amperes at 250 volts	13	6·25	4·42
Circ. mils per ampere	502	656	465
Total ampere-turns	37,752	18,450	34,158
Amp.-turns per sq. in. of pole face	482	348	1,138
Area of pole faces, sq. in.	204	106	60
Area of magnet face, sq. in.	380	233	241
Tons lifted on test	12	6	4
Weight of magnet, lbs.	1,235	1,200	300
Pounds lifted per pound of magnet	19 4	10	26·7
Pounds lifted per watt.	7·4	7·7	7·5

If it is desired to drop a plate from the bottom it can easily be accomplished by the method of quickly opening and closing the circuit, as described in the previous article. In the case of a magnet winding built up of small coils, the flashing is less severe upon opening the circuit.

There are many other arrangements of these small pole units that could be made to meet special requirements. For example, a circular structure would be well adapted for car wheels, while other special shapes to be lifted might require other arrangements. For a straight pull the round pole piece is preferable because it can be wound with a given number of turns with the least amount of wire. The table herewith gives the data for the designs illustrated.

The actual mathematical equations for predetermining the flux and the consequent required magnetizing force are very simple, inasmuch as no actual work is done by the magnet. Its function is simply to resist the force of gravity, and does not involve a space acted through. Therefore, all power absorbed by the magnet is accounted for by losses in the magnet itself. The important feature of design, then, is the correct shaping of the magnet to the work required of it, due attention being paid to first cost, and cost of repair. It always should be borne in mind that a magnet must be built to suit conditions in order to obtain best results. When this is done and a successful design produced, the owner will value his magnet at many times its cost, and generally will investigate the feasibility of putting in more of them. Like every other labour-saving device, a magnet, to be entirely successful, will often necessitate some changes in former methods of operation, but such changes are soon paid for.

The Illinois Steel Company and one or two concerns in England have had magnets in use for a long time, and during the last few months a number of other mills in this country have adopted their use. Where they have been properly built to suit the existing conditions they have been universally successful.

That this field, like every other one promising cheaper methods of doing work, will soon be invaded, cannot be doubted by any one who has seen the advantages to be gained in many cases by the use of electro-lifting magnets.

PNEUMATIC TOOLS AND APPLIANCES IN FOUNDRY SERVICE.*

By W. P. PRESSINGER.

IN discussing the employment of pneumatic tools and appliances in foundry work, it is not my purpose to describe any device not perhaps familiar to you all, but rather to present, in as brief and collective a form as the subject permits, the various appliances which have lightened labour and reduced costs in foundry service, that are dependent upon compressed air as their actuating medium.

The introduction of pneumatic tools in a form marketably perfected for shop or foundry usage dates back but a few years, and their wide-spread adoption, remarkable for its rapidity, is, after all, the most convincing proof of their commercial value. To-day a boiler shop or machine shop devoid of compressed air equipment is a rarity, and if the foundry end of our mechanical community is not so well provided for, I venture to say that it is because the merits and labour-saving properties of pneumatic machinery have not, in the rapid development of the business, been as thoroughly demonstrated to the foundry trade. The day is near at hand, however, when a foundry without pneumatic equipment cannot produce its output in commercial competition with foundries that have adopted it.

HOISTS.

The best known and most widely employed foundry appliance actuated by compressed air is the pneumatic hoist, originally used only in the straight lift, piston and cylinder form, but now utilized in a variety of types.

The vertical hoist and the horizontal style are both largely used, the latter being desirable when available head room is scant. The horizontal hoist may be arranged for a lift of two feet or four feet for each foot of piston travel, when desired. Operated by a simple three-way valve, with no complicated mechanism, these hoists are well-nigh indispensable for duty not requiring an immovably sustained load. For this latter demand, where irregular action is not permissible, a more refined type of hoist is obtainable in which the incompressible qualities of oil are used to govern and restrain the sometimes too elastic properties of compressed air. This is accomplished by providing the hoist with a hollow piston rod filled with oil, thereby preventing a more rapid movement of the piston in its upward travel, than emission of the oil through the necessary controlling valve will permit. This form of hoist eliminates that element of danger which otherwise would be present in handling vessels of molten metal, and also permits a sort of elastic positiveness which is so essentially desirable. In the actual work of moulding, as in lifting copes and moulds, drawing patterns and moving cores, the air hoists will do 50 per cent. more work in an easier and better manner, without the danger of losing castings and with considerable

* Read before the American Foundrymen's Association, Philadelphia.

saving in repairs. The peculiar adaptability of this device, properly rigged, as a drop or casting breaker, is apparent, since it is evident that the sudden release of the load could not possibly affect the regular and even progress of the piston in its return strike. This machine will break three half-pigs into three pieces each in one minute, and can easily break 20 tons of pig while a man is breaking up one ton by the old sledge method.

The motor chain hoist is a more recently developed appliance, intended for similar service, and embodies compactness of form with rapid, even speed and perfect regulation. It consists of the motor familiar to all users of pneumatic drills, so combined with a chain hoist as to permit quick movement, accurate suspension of load and prompt reversibility. One of the latest types operates the motor in a bath of oil, avoiding the annoyance sometimes due to insufficient lubrication because of the inaccessible location in which the hoist must operate. These hoists, with adequate pressure, are made in sizes to lift up to 10,000 pounds in weight, at speeds varying from 10 to 36 feet per minute.

HAMMERS.

A most useful foundry appliance, familiar to you all, is the pneumatic hammer for chipping castings; in fact, so general has become the adoption of this invaluable tool that the mere presentation of it in the accompanying view, showing its best known form of application, will suffice, supplemented by the general statement that one man with one of these tools will customarily do the work of four men following the old methods.

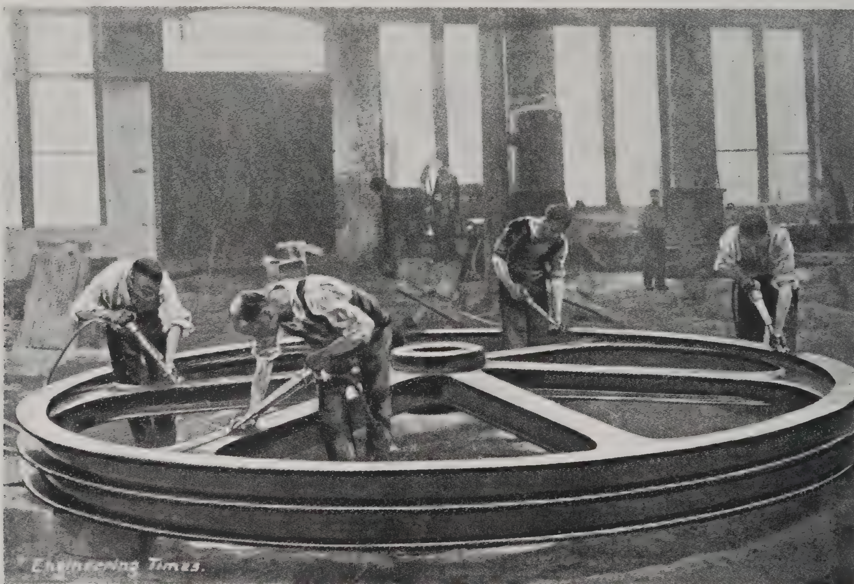


FIG. I.—THE PNEUMATIC HAMMER IN THE FOUNDRY: CHIPPING A LARGE CASTING.

DRILLS.

The air drill is another very familiar labour-saving device in some classes of foundry work, though more peculiarly a tool possessing a wide variety of usefulness in the shop, where for drilling, reaming, rolling flues, and other applications seemingly limitless, it has established itself, next to the pneumatic hammer, as the most generally used type of air tool. When a large, heavy

casting is to be broken up for return to the cupola, a small pneumatic drill may be advantageously used to drill a suitable number of small holes into which may be inserted a round taper steel wedge which, with a few well directed hammer blows, will sever the piece into parts suitable for remelting.

The application of the drill motor equipped as a casting cleaner, will appeal to you as a saver of labour and money without further argument when its immense speed and power are considered.

SAND RAMMER.

One of the most recently perfected pneumatic devices suitable only to foundry requirements, is the pneumatic sand rammer, now shown in its most improved form. Accurately counterbalanced, the weight of this tool completely rigged is not quite 300 pounds, and operated under an air pressure of 40 pounds per square inch it will deliver an average of 300 blows per minute. The maximum stroke is seven inches, but the length of stroke, and consequently the number of blows delivered, may be changed at the will of the operator by simply varying the proximity of the rammer to the work. It is estimated that a greater quantity of sand can be rammed in a more effectual manner by this machine than five men can do by hand.

SAND BLAST.

Passing from the sand rammer, possibly the newest of pneumatic contrivances to serve the foundryman's needs, we reach what to me seemed to be the oldest and one of the most widely known, though perhaps not most widely used, of them all!—the pneumatic sand blast. Embracing a broad field of application and in some way adapted to the needs of almost every known form of foundry work, the adoption of the sand blast has been retarded somewhat through patent limitations and ultra-conservative methods of introduction. Another objection has been its wasteful utilization of what was formerly a most expensive commodity—compressed air—but this element of criticism is eliminated in a great measure because of the rapid strides in the development of economical and efficient air compressing machinery. The value of the sand blast for foundry use, if obtainable at proper operating cost, being universally conceded, I will sum up my reference to this device by quoting from the pamphlet of a manufacturer, treating the subject from an argumentative standpoint:—

"The question is asked, Does the sand blast pay for foundry use? And it is answered with the qualification that it is difficult to approximate on general work. The argument continues, that on ordinary iron, steel, brass and bronze castings, one man operating a sand blast apparatus consuming 120 cubic feet of air per minute, will clean more surface and remove more cores in a given time than is possible for from six to ten men to do with hammers, chisels and brushes, and the finished work left by the sand blast is infinitely better than can possibly be produced by hand labourers. Burned sand or scale is removed rapidly by the blast, and not only does it effect a great saving in time and labour, but a further saving is effected on castings to be machined; the removal of the oxide in itself is a great saving on tools, and in many cases the tools can be run at an increased speed. This applies particularly to milling cutters. Difficult and intricate cores are readily removed, and in cleaning steel castings in which large quantities of wire nails are used, the sand is eaten away first, and subsequently the nails will fall to the ground, sand blasted, perfectly clean, and in condition to be used over again. In a number of

foundries where the sand blast has been introduced the use of facings has been discontinued. In some cases the only objection, in fact, that has been made to the sand blast is an unpleasant habit of making defects too plainly discernible."

Another recent improvement in connection with the sand blast is the application of it in conjunction with blast inserted at one or both ends of the barrel. The tumbling barrels :—These barrels run very slowly, and consequently there is slight risk of breaking a fragile casting; neither are the edges of them worn off and destroyed, as in the case of ordinary rattling at high speed. The castings are not cleaned by tumbling, but by sand ; usual time consumed in cleaning a charge of this barrel is from 20 to 30 minutes.

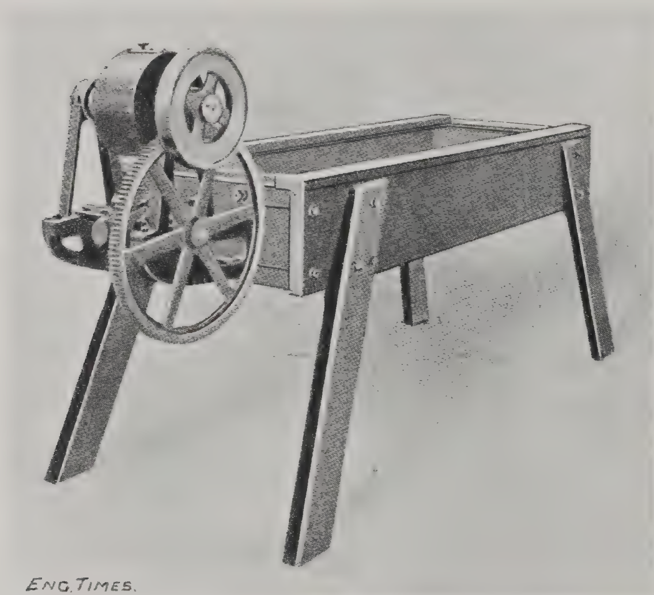


FIG. 2.—PNEUMATIC SAND SIFTER.

SAND SIFTER.

The device next shown is a pneumatic sand sifter, representing another method of utilizing the air drill motor for the needs of the foundry. With compressed air available for its operation, the value of this apparatus through saving of labour and attention becomes readily apparent. It can be moved from place to place in the performance of its work, saving the time and labour otherwise required to convey sand to a fixed sifting point.

I have refrained purposely from any detailed reference to the pneumatic moulding machine, a most important feature of compressed air foundry equipment, because the economy and value of this device have been so recently placed before you in a paper devoted to the subject. Suffice it to say that the pneumatic moulding machine presents in itself a most potent argument for the introduction of the air compressor in foundry service.

PAINT MACHINE.

The pneumatic painting machine is a simple form of compressed air device deserving a place in this paper, because of its exceptional economy for painting the interiors of foundry buildings. One man with this handy utensil can cover more space and distribute the paint more evenly than four men using ordinary paint brushes. The air consumption is moderate, and the results all that can be desired.

COMPRESSOR EQUIPMENT.

There are, of course, numerous special employments of compressed air in foundry work peculiarly adaptable to individual conditions, but not of general interest or application, reference to which is not within the province of this paper ;

but such applications suggest the inevitable conclusion that when once you have compressed air available, the number of convenient and economical possibilities that it presents to the progressive operator is surprising, and its field of usefulness in your service broadens with amazing, but none the less gratifying rapidity. Second only to electricity in its fascinating possibilities, compressed air yields nothing to electricity as a power with properties peculiarly its own, inimitable and unsurpassed in the commercial development of our time, and with the constantly rising standard of efficiency in air compressing machinery, that most important source of power which regulates the value of pneumatic appliances, more widespread adoption is inevitable. Imperfect and wasteful air compressors, possessing the primary virtues of cheapness but with all the faults in the mechanical calendar, will do more to offset the resultant value to be derived from the use of pneumatic foundry equipment, than labour antagonism, either secret or expressed. Therefore, to derive the utmost benefits from the installation of compressed air machinery, the selection of a compressor should be carefully considered. It is unwise to instal a compressor just about equal in capacity to present requirements, good practice being to provide a compressor at least 50 per cent. greater in capacity than immediate necessities demand. Compressors of the duplex type are divisible, permitting the installation and operation of one-half at first, and the other half when the additional capacity is needed. The theoretical capacity of an air compressor stated in the list of the maker is not the equivalent of the actual volume of air needed for the service. All makers list their compressors according to theoretical measurement, but the efficiency of the compressor is determined by the volume of air actually delivered with a given consumption of power. The cheap air compressor usually proves the most expensive. If a water-pump fails in its work, or if a steam-engine is deficient, the shortcomings are self-evident, but if an air compressor is poorly designed or

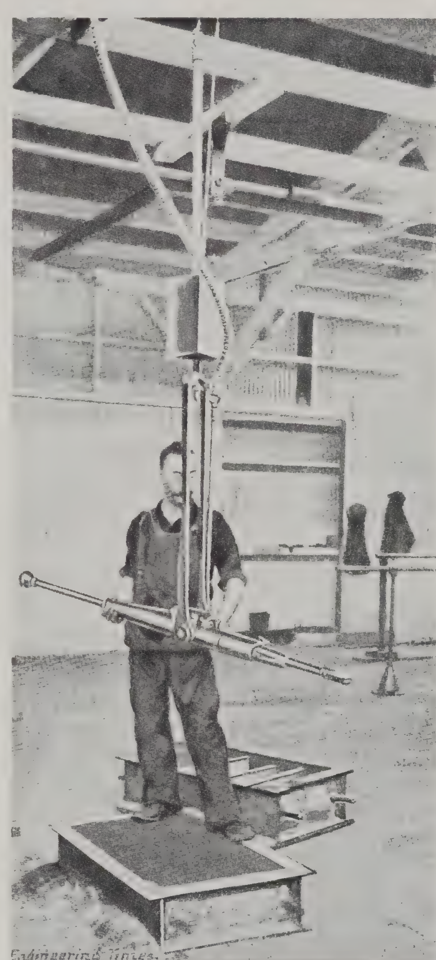


FIG. 3.—PNEUMATIC SAND RAMMER.

badly constructed, it may continue in the evil of its ways until the scrap-heap claims it for its own ; unless, as is more likely, an absolute breakdown calls attention to its deficiencies, and shows, all too late, that the hole it has made in the coal pile, added to the cost of keeping it in repair, would have paid a handsome interest on the additional first

cost of a properly-designed and properly-constructed compressor. Second-hand compressors are poor investments, unless known to have given satisfaction in service similar to that for which intended, and, in any case, the working parts should be carefully examined to see that they retain their full measure of usefulness. An air compressor with valves, pistons, etc., worn out or in bad repair, can waste a great amount of power.

The use of air-brake pumps and direct-acting compressors is very bad practice, as statistics show that their steam consumption is about five times that of a crank and fly-wheel compressor for the same volume and pressure of air delivered. Instal a steam-driven compressor, if your steam supply is plenty; otherwise a belted compressor may serve best.

Intake air to the compressor should not be drawn from a hot engine-room, or from any point where dust is abundant. The volume of air delivered by the compressor increases proportionately as the temperature of the intake air is lowered, and dust or grit entering the compressor clogs the valves, cuts the cylinders and generally impairs the efficiency.

The selection of an air-receiver should have careful consideration. Compressed air under 100 lb. pressure will leak a horse-power through a one-sixteenth inch diameter hole in five minutes, and a well-made strong and tight air-receiver is the second essentially important factor if you would realise to the utmost all the advantages which compressed air provides.

Test the air-piping under full pressure when it is installed, and at regular intervals thereafter, allowing the pressure to remain an adequate length of time, and if the gauge indicates leakage, locate and remedy it. To secure the best results and eliminate moisture from the compressed air, connect your pipe leading from the compressor to the top of the receiver, and lead your air-pipe to points of consumption from the bottom of the receiver. Proper provision should be made for draining condensed moisture at regular intervals in the system. The simplest method is to slightly incline the branches leading from the main line and insert drain-cocks before the hose connections are reached. In pneumatic equipment, as in all things else, the proverbial ounce of prevention saves the pound of cure. Experienced knowledge which the compressor maker or pneumatic tool manufacturer is ready to provide, coupled with sound calculation, will assure the highest results and utmost economy. Whether to put in a steam-driven or belt-actuated compressor; whether it should be of the duplex or single type, and have simple or compound cylinders; where best to locate the compressor and where to place the receiver; what size of receiver is adequate; whether the size of the plant warrants provision for reheating the air—all these are points requiring careful consideration. In installing pneumatic equipment it is generally desirable to procure the entire outfit from one source. Thus, division of responsibility for the successful operation of any feature of the plant is avoided, and one guarantee covers everything.

LIGHT LATHES AND SCREW MACHINES.*

By JOHN ASHFORD, A.M.I.Mech.E.

MANY changes have taken place during the last few years in the methods of machining in our various engineering establishments and manufactories, changes which are necessary in the march of progress, and which we must and do recognise as essential, in order that we, as a country, may maintain our position in the manufacturing world. These changes in machining methods usually accompany modifications in the schemes of works' management, the object being to systematise the output of work, so that prime costs may be reduced to the lowest point, while the quality of the productions, as regards both accuracy of size and fineness of finish, may be all that can be desired. In order that these new schemes of organisation may be satisfactorily worked and all requirements of the new order of things fulfilled, there has been a demand for machine tools which in themselves shall fit into the scheme, be more handy for their work, be capable of producing numbers of an article exactly alike, be automatic, where possible, in their action, and shall require little skilled attention. That the changes in themselves are great may be realised when we consider to what an extent milling processes have supplanted shaping and slotting, and, more especially, hand-finishing; how grinding is now used for finishing work that has previously been turned; and that at present automatic machines are being introduced for producing machine parts in quantities which had hitherto to be made by skilled men at a much higher cost.

In what manner these methods originated it is difficult to say; but, in all probability, they were first introduced in the manufacture of watches and clocks in large numbers; then in the production of small arms, sewing machines, type-writers and the like; and later in the construction of cycles. Engineers have now, without doubt, recognised the fact that similar methods may be employed in the manufacture of larger machines, locomotives, and even bridges and ships. These changes have not been suddenly brought about, although, to some, it may appear so; but they are, in fact, the result of steady progress. To those who have not kept abreast of the progressive movements, the changes may have been forced upon their notice with unpleasant suddenness by the experience of foreign competition. Probably there are establishments with which some of our members are connected where it is realised that alterations in the producing-plant must be made; yet there is hesitation in making the heavy outlay necessary before they have thoroughly considered the matter, and are satisfied as to the results likely to accrue.

That the matter is serious is evident from the fact that in certain manufactories whole shops have been cleared of their machines, and a completely new

* A Paper read before the Institution of Mechanical Engineers.

and up-to-date plant installed. This paper has, therefore, been prepared in order to create an opportunity for the discussion of the details of machine tools upon which much thought has been bestowed. It is intended that the term "*light lathe*" as applied in this paper, shall indicate lathes such as engineers use, the centres being below ten inches. The ordinary lathe, with which we were satisfied ten years ago, does not fulfil the requirements of the present day. There is no disputing the fact that it was a good serviceable tool, but the necessities of these times demand a machine which may be more smartly worked, be more handy, and cause less loss of time. What, then, are the requirements of a present-day lathe for tool and ordinary work, and how may these be fulfilled? In answer to the first part of this question, the author puts forward his views with all deference, and desires that members will state theirs; and, in answer to the second portion, by way of solution, he ventures to point to certain existing designs.

Let it be granted as a first principle that the machine should be stiffly constructed, and so lined up and fitted that initially it may do satisfactory work; then:—

(*a*) Its wearing parts should be made of such material and so shaped, proportioned, and protected, that its wear may be reduced to a minimum, and the accuracy of the machine be maintained, and that such wear as takes place may be compensated by adjustments.

(*b*) The various changes of speed, of traverse, of tool position, of tail-stock position, etc., should be effected by handle-movements which should be practically instantaneous in action, and within easy reach of the operator. The use of a spanner for either of these purposes is undesirable.

(*c*) A reasonable change of speed should be possible without the handling of belts.

(*d*) All ordinary speeds of traverse should be obtainable without the removal and changing of spur-wheels or belts.

(*e*) When screw-cutting or chasing from the lead screw, one movement should suffice to release the screw and withdraw the tool from the work.

(*f*) When taper turning, it should not be necessary to disturb the alignment of the tail-stock, or the set of the rest.

(*g*) Feed stops should be introduced, and also means of reversing the feed-traverse.

(*h*) It should not be possible for any two speeds of traverse to be in action at one time.

It is difficult to exactly specify the requirements of a *turret lathe*, as so much depends upon the nature of the work to be machined. It may, however, be conceded, that many of the requirements set forth in paragraphs (*a*) to (*h*), apply, with equal force, to turret lathes, and in addition the following:—

(*i*) When working from the bar, a self-centering chuck must be fitted that shall have sufficient power and range of action to securely grip the bar when subjected to its heaviest cut, and allow for ordinary variations in the diameter of rough stock whilst taking its grip without moving the stock longitudinally.

(*j*) There should be a suitable means of feeding forward the stock when required, without undue loss of time, and it should come into action immediately the chuck is released.

(*k*) The design of the revolving tool holder or turret should be such as would allow the greatest range of action; hold a sufficient number of

tools for all ordinary work; support the tool without spring with the heaviest cuts; bring the tools into action, accurately located; simplify the construction and setting of tools and their holders; and revolve and locate itself automatically.

(*l*) Independent stops should be provided for each tool, and, when the turret traverse is actuated by power, the stops should throw out the power mechanism.

(*m*) The means of traversing the turret should be such as to allow of quick movements while changing the tool positions, and steady motions while cutting.

(*n*) A cross slide is usually desirable to carry forming, cutting-off, and chasing tools, and its position should be easily and accurately adjustable.

(*o*) In many cases, especially for brass work, efficient means of chasing should be introduced, and if, for this purpose, a leader screw is used, excessive wear of the screw should be guarded against.

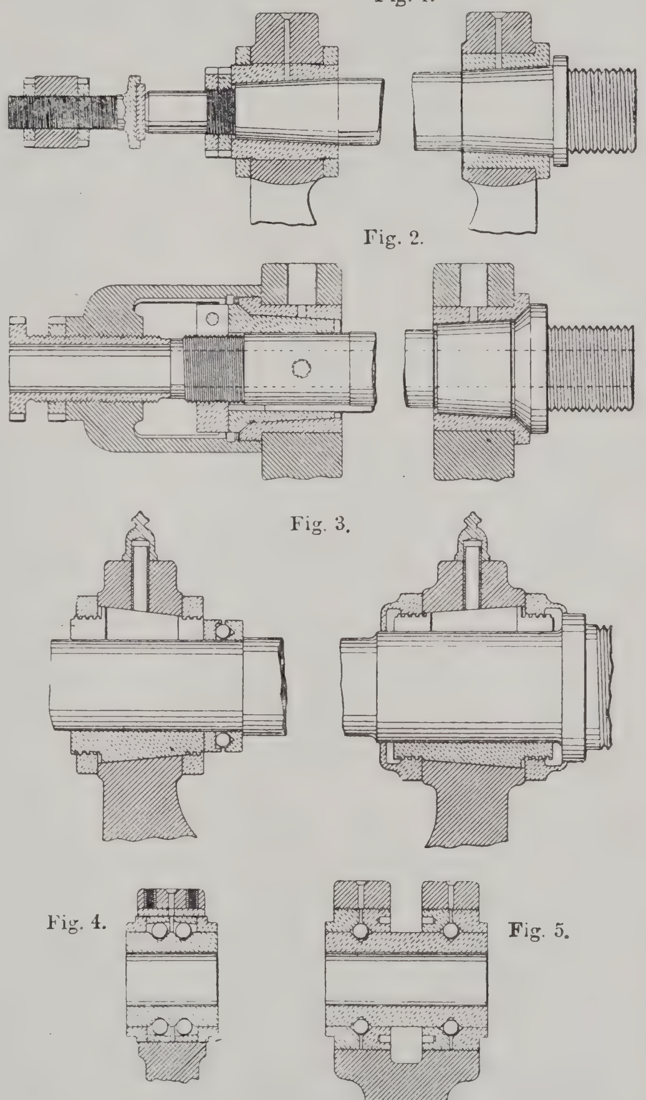


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

DIFFERENT FORMS OF SPINDLE BEARINGS.

Full automatic screw machines, suitable for automatic turning in addition to screw-making, may be considered to be modified turret lathes, with mechanism added to automatically regulate the various movements. The requirements of the turret lathe thus apply also largely to this class of machine, and in addition the following:—

(*p*) The headstock should retain some of the features as in the turret lathe, with modifications adapting it to automatic working. The speed of spindle rotation should be variable to a limited extent; but the introduction of self-opening dies has

rendered it unnecessary to provide any reversing mechanism.

(*q*) A cam-shaft must be introduced to regulate the movements of the various parts, and, as the speeds of the movements are required to vary, the cam-shaft speed should be changeable, this speed variation being quite independent of the spindle speed.

(*r*) It is a debatable question as to whether the turret carrying the tools should have a constant or a variable distance of forward traverse. The settlement of this point greatly affects the design of the machine, and, in the author's opinion, the correct answer to the question is, that unless the scope of the machine is to be very much restricted, the forward traverse should be variable.

(*s*) The mechanism controlling the tool movements should provide for a rapid withdrawal of the tool and change of position, so that idle time may be reduced to a minimum.

The question now is:—How may the requirements of the foregoing paragraphs best be fulfilled; and to what extent do they affect the construction of the machines?

Fig. 6.

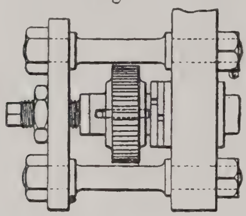
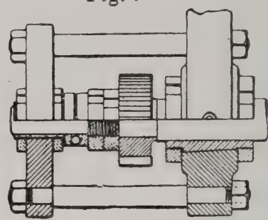


Fig. 7



THRUST BEARINGS.

Respecting paragraph (*a*), the wearing parts which affect the accuracy of the machine are:—The journals and bearings of the spindle; the various slides and slide surfaces; the screws and their nuts.

That a wearing surface may act satisfactorily, it is recognised that the following conditions should be fulfilled:—

(1.) That any pressure brought to bear upon it should be evenly distributed.

(2.) That it should be protected from dirt of every description.

(3.) That it should be efficiently lubricated.

(4.) That the surface itself should be sufficiently large.

(5.) And finally, its formation should not admit of any pressure brought to bear upon it being mechanically increased to any serious extent.

Fig. 8.

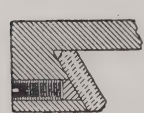


Fig. 9.

Fig. 10.

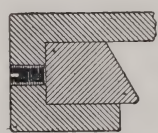
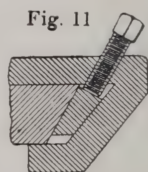


Fig. 11



ADJUSTING OR GIB-STRIPS.

LIGHT LATHES.

The Spindle.—It is a point for debate as to whether the spindle should be hard or soft. In the opinion of the author, it is of much more importance that the bearing surface should be large, and that the journals be made truly cylindrical.

The Bearings.—As materials, each of the following are found to have been

used:—hard steel, cast-iron, phosphor-bronze, and brass or cast-iron lined with white metal. When the bearings are small, no doubt hard steel is desirable, but if they are of ample proportions, it becomes unnecessary. Too soft a metal, on the other hand, is not satisfactory, as it does not last well enough. Both phosphor-bronze and cast-iron may be considered suitable:—that is, if the bearings are well bedded and of sufficient diameter and length to satisfy condition (4) respecting wearing surfaces.

Several different forms of spindle bearings are shown in Figs. 1 to 5. The conical construction, as in Figs. 1 and 2, has the rather serious objection of failing to comply with condition (5) *re* wearing surfaces, for, should the thrust-bearing be improperly adjusted, the cone will be forced more deeply into its bearing, thus increasing the pressure on the surface, thereby creating excessive friction. The cone-bearing, in fact, does not lend itself to either of the conditions (4) or (5), as, with a reasonable taper, the bearing is short; but if, on the other hand, the length is increased, there is a finer taper which still further violates condition (5).

The author prefers the design shown in Fig. 3, where the bearing surfaces are parallel and the exterior of the bearings are coned. The bearing is split is one place and eased in two others, thus making a springy bush which, when adjusted longitudinally, will close upon the journal. This retains the advantage of the cone adjustment with a parallel bearing. In this same bearing, conditions (2) and (3) are well satisfied, there being a felt oiling-pad introduced into the split of the bush and dust-caps over the ends of the bearings. Halved bearings are very largely used, and ball-bearings, as in Figs. 4 and 5, have been tried.

Thrusts.—With the cone-bearing, an adjustable end-thrust, such as in Figs. 6 and 7, is necessary, but, when parallel bearings are used, a non-adjustable ball-thrust is satisfactory, and it may be placed inside the poppets, thus adding to the compactness of the headstock. Ball end-thrusts may be seen in Fig. 3 (and Fig. 28 and Fig. 53, to follow).

Adjusting or Gib-strips.—Several different arrangements of these strips are illustrated in Figs. 8, 9, 10 and 11. Those in Figs. 10 and 11 should undoubtedly be used where possible, and the strip should have sufficient metal in it that only two adjusting screws may be necessary. It cannot be considered good practice to use thin strips with three or more grub-screws for adjustment.

Slide Surfaces.—That slide surfaces may wear well, the conditions as to wearing surfaces should be met as fully as possible. When the force applied for the purpose of traversing a slide is not central with the resistance, a couple results, with a tendency to twist the slide. A very small angle of twist causes condition (1) to be violated, consequently, unless the strips are so adjusted that there is no slack, the condition cannot be satisfactorily complied with. This logically leads to the following conclusions:—(1), either the screw or other means of traversing the slides must be in line with the resistance; or (2), where that is impossible, as it usually is, and as an ordinary machine operator cannot be depended upon to keep the strips correctly adjusted, the adjustments must be automatic; or (3), the guide surfaces in contact should be very long. From these points of view, it is evident that the nearer a traverse-screw is to the centre of the slide-ways, the better. The usual practice with the slide-rest conforms to this, but not so with the saddle, although some firms put the lead-screw in the interior of the lathe-bed.

(To be continued.)

NEW MACHINERY, APPLIANCES, ETC.

(Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.)

"WORTHINGTON" WATER TUBE SECTIONAL BOILER.

FOR general power purposes English makers do not favour the practice of building boilers complete in themselves, and in which brick and masonry are dispensed with, but this design of boiler is becoming increasingly popular in the United States. True, there are one or two—such as the "Climax"—being built in this country, but even they are of American origin. The argument used against the brick-set boiler is that it continually needs repair; cracks develop in the brick setting, often making inlets to the furnace for cold air, thus also reducing the temperature. It is also argued that it occupies more space and costs more for foundations.

We illustrate an American Water Tube Boiler which has some interesting features.

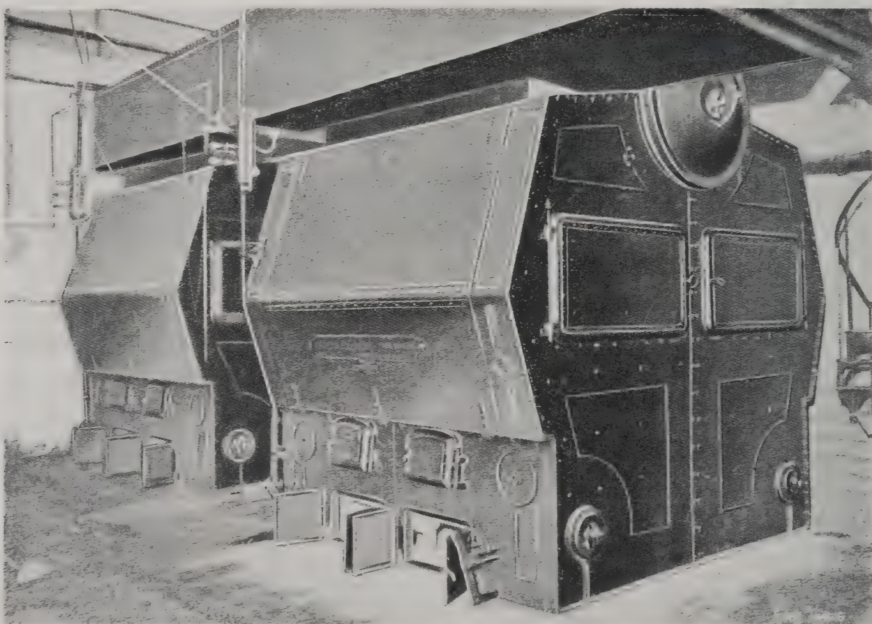


FIG. 1.—VIEW SHOWING AN INSTALLATION OF TWO "WORTHINGTON" WATER TUBE BOILERS.

This boiler belongs to the sectional water tube type. It is entirely enclosed in air-tight iron casing. An arrangement of doors makes every part of the interior construction readily accessible for cleaning

and repairs. The casing is lined with asbestos non-conducting material of a tough and durable texture to effectively prevent radiation. The mud drums extend through casing, and are provided with hand hole plates which are accessible from the outside, when examination is considered advisable. The tubes are arranged directly over the furnace in oppositely inclined sections, several tubes high. Every tube is in the fire, and it is claimed therefore that every square inch is thus employed as heating surface.

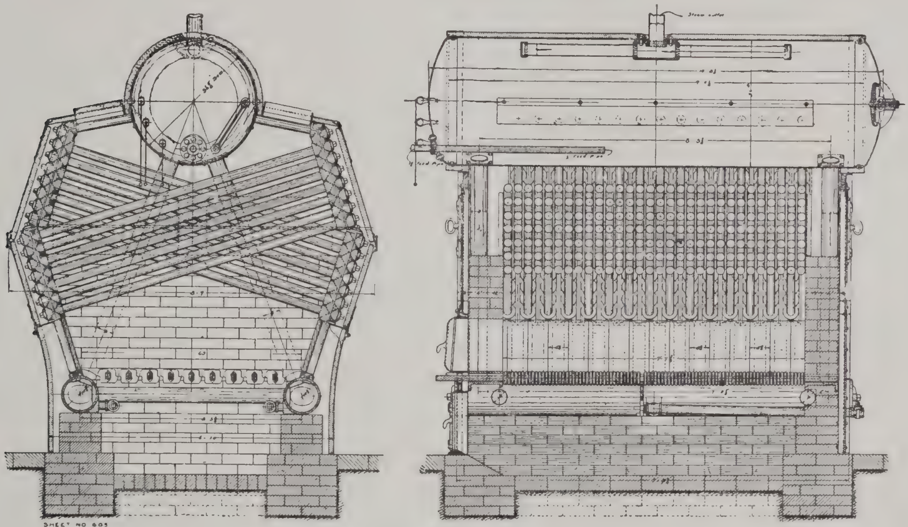
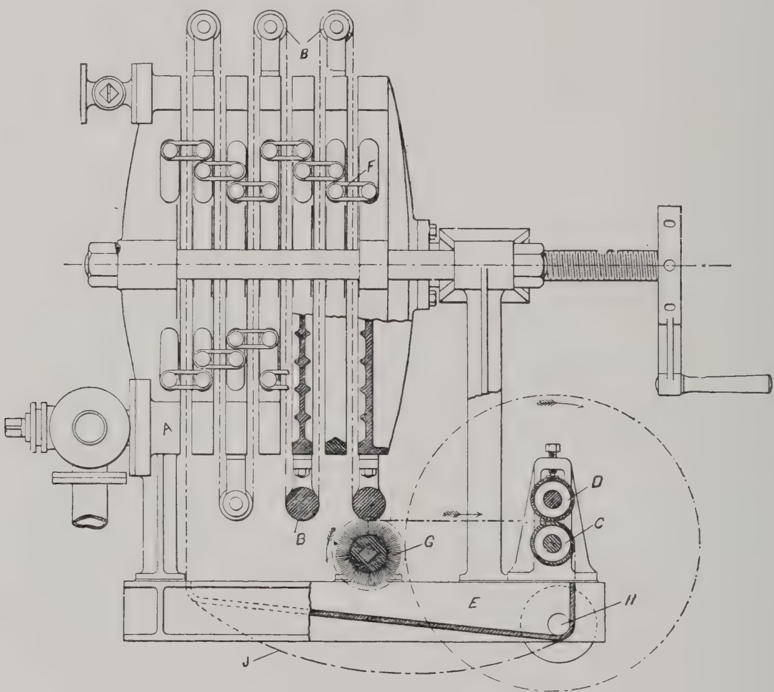


FIG. 2.—END AND SIDE SECTIONAL VIEWS OF THE "WORTHINGTON" WATER TUBE BOILER.

The circulation in this boiler is as follows: From the steam and water drum located above the tubes, into which the water is fed, it descends the water legs (four in number) placed outside the furnace, to the mud drums at the base; thence it passes *viâ* the tube connections into the lower series of headers; thence through the tubes over the fire into the upper series of headers; thence *viâ* the tube connections into the steam and water drums from whence it started. The downtake tubes are shown in the end sectional view by dotted lines. When steam is generated in a boiler, its immediate and free transit to the steam reservoir is necessary. It should not be impeded by devious channels, or concentrated at one point common to the entire boiler, and thence emerge with a degree of violence out of keeping with the action in other parts of the boiler. Such concentration and delivery, through a contracted passage, means unnecessary disturbance in the steam drum, where quiet should prevail. Its effect is felt throughout the boiler, and the direct results are, irregularity in motion of the water contents of the boiler, an unsteady water line, and wet steam. When steam is being rapidly generated and promptly withdrawn from the steam drum for use, it becomes a matter of great importance that the flow from the various tubes shall be steady, gentle and devoid of commotion. The steam delivery arrangement of the "Worthington" boiler is such that each section has its own independent outlet for the steam made in that section; and the inlet to the drum is in the side of same, and approximately at the water line. Thus, a boiler composed of, say,

twenty-four sections, has twenty-four separate connections with the steam drum. In a boiler built in sections of $2\frac{1}{2}$ in. tubes, seven tubes per section, each 7 ft. long, each section represents about 4 h.-p.

By reason of its sectional character, it can be delivered in places wholly inaccessible to many boilers. A boiler of 200 h.-p. can be passed through a 4 ft. by 4 ft. opening, doorway, or window.



EXPLANATORY VIEW OF THE "WILSON" FILTER.

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THE "WILSON" FILTER.

WE give herewith a vertical side elevation and part section of a new filter or filter-press. Previously in this type of filter, the filtering medium, consisting of flax or cotton cloth, has been cut up into separate pieces for each chamber. When the interstices of the cloth were clogged up by the fine matter contained in the liquid being filtered, it was necessary to remove each cloth by hand, wash it also by hand or by a separate washing machine, and then replace it on the frame or plate, as the case may be. This is altogether avoided in the "Wilson" filter, and the improvement marks another step in the direction of economising on hand labour. By means of parallel rollers B, attached to the frames and plates, the cloth J is manipulated as an endless band, and when drawn through the nipping rollers C, D in the direction of the arrow, is brought into contact with a brush, or brushes, G, rotating at a higher speed and in the contrary direction. That is the gist of the invention, and the result is that what formerly occupied the space of hours, and involved corresponding labour, can now be accomplished in considerably less time. The links F enable one man also to open out the

elements of the filter expeditiously and into their proper positions while the bed-plate E, with drain pipe H, serve to remove the brushings in a clean and convenient manner. These circular brushes have been found to be most satisfactory in their action. In many cases where filters of this description would have been welcomed for the large area they provide within a limited space, their use was impracticable, owing to the excessive time and labour involved in cleansing the filtering cloth ; but with the adoption of these brushes in combination with a travelling cloth, this disadvantage has been entirely got rid of. The apparatus works with the utmost smoothness, and the results obtained, so far as filtration is concerned, have been remarkably good. The patentees and manufacturers are The Wilson Filter Syndicate, Limited, Fyfe Chambers, 105, West George Street, Glasgow, on application to whom one of these filters may be seen in operation.

AN HOUR AT THE PATENT OFFICE.

(Selections from recently published Patent specifications. Complete copies may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, E.C. Price 8d. each.)

No. 21,942 of 1899. H. H. Gudgeon, of London, for "Apparatus for Watering Cutting Wheels on Lathes."

The apparatus consists of a reservoir for holding water or any other fluid, to which is fixed a spindle working in bearings in two standards placed vertically in a base of heavy metal. A cap fixed in the top of the reservoir can be removed to fill the same. A wick passes through the cap, and rubber tubing passes over the wick and part of the cap. The wick can be drawn past the end of the rubber to touch the wheel, scratch brush, or other object to be moistened. The rate of flow of the water or other fluid is regulated by a screw passing through a projection arising from the cap, which presses a piece of springy metal also arising from the cap against the rubber tubing containing the wick, which is buttressed by a projection arising from the other side of the cap. Slots are cut in the standards, which admit of the reservoir being raised or lowered. To put in use, the reservoir is turned over towards the wheel, or the like, to be moistened, and is put into position by an adjustable upright fixed to front of base. The fluid passes through the wick partly by capillary attraction, and partly by gravity.

◆ ◆ ◆

No. 22,843 of 1899. W. D. Hamilton, of Bearsden, Dumbartonshire, for "Water Tube Boilers."

The under part of the boiler shell near each end is dished or creased into a horizontal, or nearly horizontal, surface, and the nipples from the headers are connected to the same, the nipples being practically in a straight line. The headers are formed of a straight shape, and preferably of square section, and are connected to the steam drum by the straight nipples, as described. Bricks are placed between the tubes at distributed distances apart, for the purpose of baffling and staggering the flame.

Between each row of tubes in the side walls, hinged cleaning doors are fitted at an angle to open inwardly, and to close automatically when the steam cleaning pipe is withdrawn. Hand holes are formed in the headers opposite each tube for easy access to the latter.

* * *

No. 24,005 of 1899. T. B. Browne and F. L. Martineau, both of London, for "Steering Gear of Auto-cars."

The steering wheels are mounted on stud axles, with vertical or like pivots, and rearwardly projecting steering arms. The end of these arms are connected by a single cross-bar, the extremities of which are jointed thereto. On the middle of this cross-bar a third arm is secured in such a way that it may be adjusted and locked exactly in the centre, or somewhat out of centre, if the other parts of the steering should require it. The steering handle is preferably fixed to the top of an inclined steering stem mounted revolubly in a socket on the body, and similarly mounted in a second socket to the under frame of the vehicle by longitudinal and transverse radius bars, so that the motion of the body and springs does not materially affect the position or movement, rotatively considered, of the foot of the steering stem. To the said foot of the steering stem is secured a fourth arm, which is also preferably rearwardly directed, and connected to the third arm.

* * *

No. 24,036 of 1899. S. H. Baker and W. H. Baker, both of Bracknell, Berks, for "Fire-bridge for Furnaces."

The furnace fire-bridge (which is made hollow) is constructed to somewhat overhang the furnace, fresh air being admitted to the interior of the bridge from below the firebars. The air so admitted passes into and through the overhanging part of the bridge, and becoming thereby highly heated, is delivered in this condition by valve or shutter controlled apertures in the upper part of the bridge, where it meets and commingles with the products of combustion. The delivery apertures are located both at the front and back of the upper part of the bridge, and also at the top of the fire-bridge, and the shutters for controlling these apertures are connected by levers, link and the like, that they may be conveniently operated from the front of the furnace.

* * *

No. 25,114 of 1899. R. J. Melius, of United States, for "Apparatus for Elevating and Conveying Coal, Grain, and the like."

The apparatus consists of a suitable guide frame, which is arranged at an inclination, and consists of side pieces, arranged parallel, and connected at intervals by transverse stays. The spaces between the stays are fitted with doors capable of opening inwards. Sprocket wheels are journalled at the upper and lower ends of the frame, and an endless chain, carrying buckets, travels over them. The backs of the buckets are hinged at their upper ends to open inwardly by the action of gravity, when they arrive opposite to one of the doors in the frame which has been opened, and to be closed by contact with the next stay, which it passes as it travels. A trough or chute is arranged with one of its ends between the chain, and is capable of being tilted to catch the contents of the buckets as they pass one or more of the doors which are open.

* * *

No. 25,234 of 1899. M. J. Oliver, of Bere Ferrers, Devon, for "Automatic Couplers for Railway Vehicles."

A combination or jointed link is hinged to the ordinary draw-bar, or to a horizontal lever attached to the end of the carriage or truck, with spring hinges. When the said link is attached to the draw-bar, a swivel is also provided to the hinder part of the link,

through which a cross lever attached to the said horizontal lever works. At each end of the said horizontal bar handles or levers are connected at right angles, the said handles working in sweeps with stop bolts, to keep the links in the required positions.

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No. 25,612 of 1899. J. Cleland, of Down, and J. C. Stewart, of Belfast, for "Steam-trap."

The steam-trap consists of an outer casing of iron tube, on one end of which is screwed a coupling, and on the other end a tee. Into the outer end of the coupling is screwed a thimble, the outer end of which is tapped for joining the trap to the steam-pipe, and the inner end forms a valve-seat. Into the outer end of the tee (which is at the other end of the trap) is screwed a brass plug, which is bored and tapped to receive a set screw having a jamnut. Between the inner end of this set screw and the valve-seat is placed a piece of brass tube having a conical valve fixed on one end, the other end resting on the inner end of the set screw, by means of which the conical valve can be regulated or adjusted to its seats.

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No. 8,417 of 1900. H. Braby, of Queensland, for "Steam Generators."

One or more generator blocks or plates of good heat-conducting material are provided, having passages or water-ways therein, through which the water is made to circulate. One or more of the plates may be perforated, through which perforations or holes part of the furnace heat is made to pass. The caps which return the water-ways and give access for cleaning purposes are jointed, preferably by means of asbestos rings recessed into the plates. A back-pressure valve is provided for the water inlet from a feed-pump or injector, and preferably a back-pressure valve for the steam outlet, which may be led to an equalizer or dome, from which a pipe connects to an engine or other steam consumer. A return water-pipe, provided with a check valve, leads from the equalizer to the water inlet. The equalizer is so situated over the furnace or combustion chamber as to receive part of its heat.

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No. 9,624 of 1900. A. Bever, of Dewsbury, Yorks, for "Internal Combustion Engines."

An internal combustion engine, in which a working cylinder and a partial vacuum cylinder connected with a vacuum reservoir are placed tandem to each other. The working cylinder is constructed in such a way that the front portion projects sufficiently far into the vacuum cylinder that ports may be cut through the body of the cylinder, and be uncovered by the piston at the front end of the stroke.

• • •

No. 15,161 of 1900. E. R. Royston, a communication from W. Hoy, of Bristol, for "Lubricators."

The oil supplied by the lubricator is delivered by a ram working in a cylinder, and operated by a piston and cylinder connected with it; and the motive power which moves such piston to and fro is a vacuum, preferably that existing in the condenser, and created by the engine with which it is employed. The operating cylinder is alternately put in and out of communication with the vacuum or condenser, and in and out of communication with the atmosphere automatically by means of a valve gear operating from a moving part, such as a connecting rod of the piston of the actuating cylinder. The lubricating oil is introduced into the ram cylinder through an inlet valve, such as a lift or non-return valve, and discharged from it through a similar valve, such valves working in the manner of liquid pump valves; and the rate of supply or discharge is regulated by means of a screw-down plug, or the like, working in

connection with a part of the delivery conduit for the oil forced by the ram, whereby the area of the conduit is varied and regulated as desired. Consequently, as the area is diminished or increased by means of this plug or regulating device, the rate of action of the lubricator and the quantity of oil delivered by it, for each unit of time, is controlled or governed.

No. 2,053 of 1900. A. Reichwald, a communication from the firm of Fried Krupp, Essen, Germany, for "Hydraulic Brakes for Ordnance."

A hydraulic brake for ordnance, in which the throttling of the liquid is effected by the aid of openings in the walls of the return piston (which piston is in the form of a hollow cylinder closed at one end), the said openings decreasing in cross section from the closed end toward the open end, the said openings passing over inlet ports for the liquid in the walls of the return cylinder, as the return piston moves, and reducing more or less the cross-sectional area of the liquid passages, according to the position of the return piston at any particular moment.

⁂

No. 4,564 of 1900. J. Hopkinson, J. Hopkinson & Co., Ltd.. and J. Lowis, all of Britannia Works, Huddersfield, for "Safety Valves."

A lever is provided having an eye at one end, which surrounds the valve spindle, or the barrel part of the crutch or bonnet or other device attached to the upper end of the valve spindle for the purpose of turning the same, and which lever is furnished with upper and lower fulcrum points on each side of the eye, the upper fulcrum points acting against the under side of the collar of the crutch or other device attached to the spindle, and the lower fulcrum points resting on the lid or cover of the valve. The said upper and lower fulcrum points or projections are arranged out of alignment, so that when the lever is operated the valve is raised.

⁂

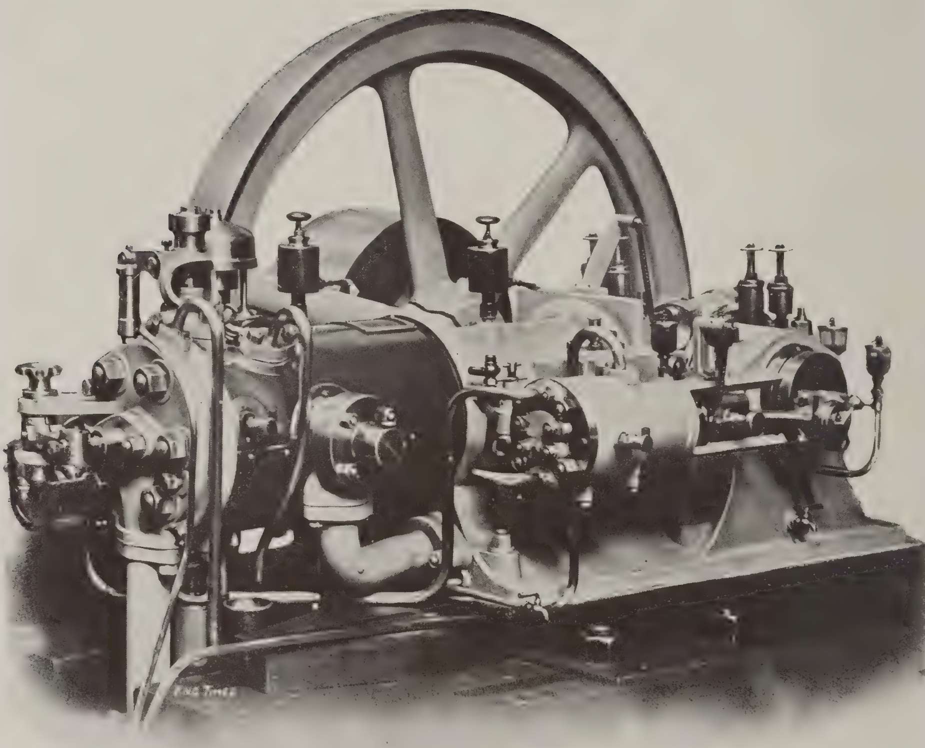
No. 16,634 of 1900. A. R. Mosler, of United States, for "Steam Boilers."

A boiler for flashing water into steam as it is fed to the interior of the boiler, consisting of flanged tubular sections exposed to the products of combustion, and provided on their interiors with means for laminating the steam, whether a convolute coil, a bundle of graded rods, or perforated blocks arranged in staggered order, and whether the flanged tube be circular or straight, and composed of one or several parts. The boiler can be removed bodily from the furnace at pleasure.

⁂

No. 16,668 of 1900. C. Landeker and F. Albert, of Germany, for "Driving Pulleys."

The single pulley or single steps of the pulleys are made in the well-known manner, by pressing or drawing from a sheet of metal, preferably iron or steel, and by which process a round vessel or cylinder is produced. Through the bottom of the vessel is punched a hole or opening, which corresponds to the diameter of the next smaller step or pulley. The straight flange of the vessel is, in diameter, a little larger than the inside diameter of the next step or pulley, and by forcing this flange against the face of the next step or pulley, a permanent connection of the several steps or pulleys with each other is made.



THE FIRST BRITISH-MADE "DIESEL" ENGINE.

19 *B.H.-P.* *Stroke*, 10¾ *in.* *Diameter of Cylinder*, 7⅞ *in.* *Revolutions p. m.*, 210.
Makers: Messrs. Scott & Hodgson, Limited, Guide Bridge, Manchester.

The Engineering Times.

Vol. V. APRIL, 1901. No. 4.

Municipal Electrical Engineers.

One of the most striking features in connection with the development of municipal electrical undertakings in this country has been the constant changing about among borough electrical engineers. Those who have watched the course of events since, say, the early nineties can point to central station men who, to-day, are in the forefront of the profession, but who then were just sprouting out as resident engineers, with their modest £150 or £200 per annum. Some of them moved from this station to that as openings occurred, acquiring new experience, and, at the same time, unlike the proverbial stone, they gathered considerable moss. In a number of cases the official position brought with it a certain amount of work in the nature of a consulting practice, and presumably percentage fees became more acceptable than a fixed salary, for not a few men have forsaken station work to take up expert work in which they are not subjected to the officious intermeddling of their many masters on municipal councils. Far be it from us to suggest that this change is an undesirable one; for the man who has been trained as an electrical engineer, and has had actual experience in the operating of lighting or tramway stations, seems to be eminently better fitted to advise as to the lighting or tramways for a new district, than is the man who, having passed through the technical schools, at once proceeds to dub himself "consulting electrical engineer," competing for "jobs" and so on. But, notwithstanding the unparalleled electrical development which is now taking place, we must confess that we have sometimes thought that the consulting element was becoming unduly large, particularly bearing in mind the tendency among municipal authorities to allow their resident engineers to supervise the carrying out of their extension schemes. There is no lack of first-class men for running municipal works; on the other hand, when a responsible berth is going, there is a remarkable eagerness—witness the case of Manchester, where, during the past few weeks, Prof. A. B. W. Kennedy has been reorganizing the electrical department. Here the number of applicants for the position of "chief" was 212, the successful one being Mr. C. F. Metzger, who has controlled the City of Bath Electric Light Works for some years. The salary was £800, rising to £1,000, and the provincial towns of lesser importance are bound to lose their officials when the larger cities are offering these attractive incomes. Another case we may cite is that of Mr. J. H. Rider, who has so successfully run the Plymouth Corporation electric lighting and tramway combined system during the past year or two, and is now coming to London as the London

County Council's electric tramway engineer, at a salary of £1,000. Mr. Rider will have vastly more extensive and important matters to handle in London, but he has had a wide and varied experience in English municipal works, and has recently visited America to inspect electrical works there; and we have no doubt he will be quite equal to his new duties. Mr. C. D. Taite is leaving Southport works for Salford; Mr. Vesey Brown is leaving Lincoln. The changing about of two or three leading electrical engineers leads to more or less of a shaking up all round the country. The effect upon the station and system generally when these changes take place varies according to circumstances. The newcomer may settle into the groove of the late engineer without much difficulty, but this is not invariably the case; the new man has new ideas on some points, and thinks things might be done differently. The result may not always be satisfactory, but for the present such changes appear to be inevitable.

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Export Engineers and Colonial Telegrams.

It is with great satisfaction that we observe that the Government has at last seen fit to appoint an inter-departmental Committee to inquire fully into the question of telegraphic communication with our Colonies and other dependencies. The Chambers of Commerce of the United Kingdom, and commercial men generally, have long recognised the insufficiency of the existing service, and with the very able assistance of Sir A. Sassoon have driven the matter well home, with the result that the Government and most of the commercial public appreciate the ever-increasing necessity for extensive, inexpensive, and unrestricted telegraphic communication between the Mother Country and all parts of the British Empire. Among the Committee's duties will be to consider where, and in what manner, the existing lines need supplementing, and also to show how reductions in rates per word, if necessary, are to be brought about. To the engineers and machinery manufacturers of this kingdom, who are making great efforts to push export business, the matter is one of supreme import, and we wish the Committee success in its labours. Its findings will certainly be awaited with great interest.

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A Solar Motor.

The idea of utilizing the sun's heat for generating steam is an old one, and numerous devices for concentrating the heat of the sun have been experimented with. One of the latest of these was recently erected in South Pasadena, California, within the enclosure of the ostrich farm, where it can be manipulated with least bother from persons curiously inclined. The contrivance was erected by an American firm for a party of Boston inventors whose names have not been made public. The selection of this locality was owing to the favourable climatic conditions, there being usually but few cloudy days in the year.

The machine referred to is of simple design, and with the aid of the accompanying illustrations* is readily comprehended. It consists of a large umbrella-shaped reflector with a tubular-shaped boiler in position corresponding to the handle of the umbrella (Fig. 1), to absorb the reflected heat. The reflector is set in the meridian, on two framed supports or towers, in a manner to balance the entire frame. It rests on an equatorial mounting, like a telescope (Fig. 2), the axis being due north and south, and the machine turning east and west in following the sun. The reflector

* From "The Railway and Engineering Review."

FIG. I.—SOLAR MOTOR AT SOUTH PASADENA, CALIFORNIA. FRONT VIEW.

is 33 ft. 6 in. in diameter on top, and 15 ft. on the bottom. It contains 1,788 mirrors, about $3\frac{1}{2}$ in. by 24 in. in size. The weight of the reflector is about 8,300 lbs.

The boiler is 13 ft. 6 in. in length, with a capacity for 100 gallons of water and 8 cub. ft. additional steam space. The boiler is made of fire-box steel, covered with an absorptive material, of which lampblack is one of the principal ingredients. Steam is conducted from the boiler to the engine by flexible pipe, connection being made at the base of the machine, where the movement is confined to a very slight circle.

When it is desired to fire up the boiler, in the familiar way of expressing it, the reflector is swung into focus by turning a crank. There is an indicator, which shows when a true focus is obtained. This done, the reflector follows the sun all day, the movement being regulated by a common clock. Steam can be raised in about an hour after sunrise, and the operation of the boiler is effectual until sundown.

From the boiler the steam is conducted to an engine close at hand, which is geared to a pump for the purpose of testing the rate of work which the machine is capable of doing. According to some accounts, the all day average work performed by the engine is 1,400 gallons of water lifted 12 ft. per minute, which is at the rate of 4 h.-p. The indicated power of the engine is not stated. The photograph from which Fig. 3 was reproduced we can personally vouch for as a genuine likeness of the machine, but the above data were not obtained at first hand.

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Blasting with Liquid Air.

Oxyliquit is the name under which liquid air, absorbed by some suitable material, is being used in Germany as a blasting agent. During last autumn the Prince Regent bridge had suffered from the high flood of the Isar, and

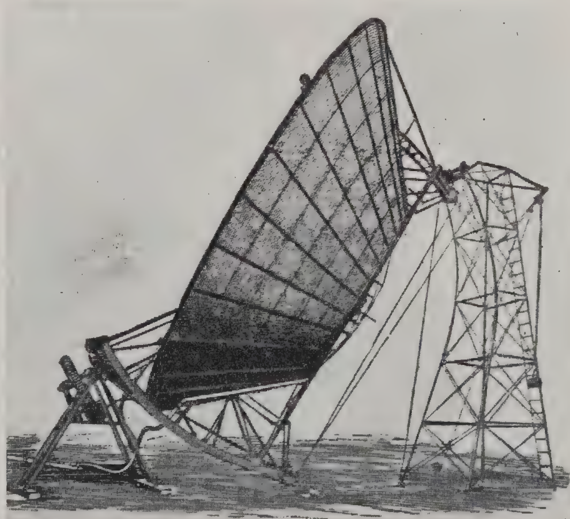

FIG. 2.—SOLAR MOTOR. SIDE VIEW.

large bulks of stone and concrete had to be blasted. The cartridges were made of paper, filled with an oily mass and provided with a primer. When everything was nearly ready, the liquid air was brought down to the river in a vessel fitted with a vacuum jacket, and the cartridges were placed in the liquid air. They were soon taken out again, fixed in the usual manner, and fired by the electric spark or by a Bickford fuse. The effect is said to have been equal to that of dynamite. If a cartridge missed fire it turned harmless again within a quarter of an hour, because the oxygen evaporated rapidly.

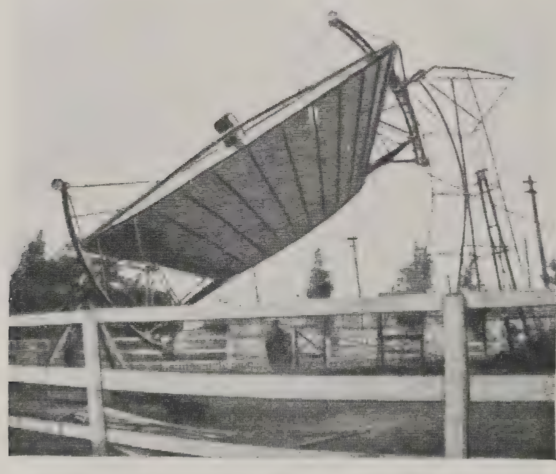

FIG. 3.—REPRODUCTION OF ACTUAL PHOTOGRAPH OF SOLAR MOTOR.

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Accumulator Traction.

During the past year or so electric traction by accumulators has been more or less extensively tried both on the Continent and in America, but, unhappily, the reports of the practical outcome of the application have not reassured those who recognize in battery tramways not only an ideal form of street locomotion, but, as they have assumed, one which was on the verge of being commercially practicable. Hearing, as one has done, quite recently of the abandonment of electric batteries from the thirty odd miles of line from Chicago to Englewood, of the intention to remove them gradually from the streets of Berlin, and other instances similar in effect which we might cite, it were but natural to assume that the immediate prospects for battery trams were anything but rosy. We might go further, and quote also the Birmingham system, where, on a short section, batteries have been employed with indifferent and varying success for the past ten years. Last year it was resolved, for some reason or other, to turn off the battery cars, and substitute the overhead trolley wire principle. This is now being done. It is, however, extremely interesting to note in this connection what Mr. G. A. Grindle, M.I.E.E., has to say. Mr. Grindle, it should be mentioned, through his connection with the Chloride Electrical Storage Syndicate, is in a position to know just what has, and has not, happened with the Birmingham cars running by means of Chloride secondary cells. Although admitting that the Birmingham battery line has been anything but a success, he states that this result has been brought about owing entirely to the nature of the equipment and the capacity of the line. Up to the year 1894, with other batteries doing service, the losses were said to be due to the cost of the up-keep of the cells; but since that date no data of running costs have been forthcoming. Yet it is a fact that batteries have been supplied, and car miles run to the extent of over 1,100,000 miles, and the result, we are told, has been "highly satisfactory from the accumulator view of cost."

As matters now stand there is no battery line, pure and simple, in operation in England. It appears that a

great effort is being made to prove its capabilities on Thirty-fourth Street, New York, and every one interested in electric traction developments will be interested in the attempt, and what follows it.

Conduit Tramways.

Unless the most unexpected happens, the London County Council will very soon be proceeding with the construction of underground conduit tramways. As has been already intimated in these columns, the Council has a short experimental line on the Westinghouse principle operating at its Camberwell depôt, and at the same place there has recently been inspected a short length of track devised by Professor Kennedy expressly for its application to London streets. We are not aware what will be the decision of the municipal mind as to the relative merits of the two systems, nor do we know what special qualifications such elect representatives possess for weighing them in the balance. Presumably a short length of actual street line will be equipped on one of the principles, and perhaps on both; but we have our fears that the Council will continue to experiment further before it takes the great plunge necessary to give Londoners the so necessary electric service. In view of the great interest attaching to the problem, the paper read before the mechanical engineers by Mr. A. N. Connett on "Combined Trolley and Conduit Tramway Systems" comes at a very opportune moment. The author recommends the open slot conduit for congested thoroughfares, with the overhead trolley for outer streets. The problem of adapting the plough and track mechanism to change from the overhead line to the conduit system, or *vice versâ*, has been satisfactorily and carefully worked out on several different principles on the Continent. Mr. Connett's opinion is that for the particular character of tramway work in this country, Continental systems contain more of practical interest to English engineers and local authorities than do American. With the side slot the principal trouble arises with the switch at the junction of two slots; but this difficulty is stated to have been overcome by a special construction, which was described in the course of Mr. Connett's paper. The illustrations and notes regarding several special pieces of side slot conduit work now operating in Paris are worthy of careful study.

Power Supply.

The necessity for a cheap and plentiful supply of electrical energy is very pressing in our great manufacturing districts. The evidence which was given before the Select Parliamentary Committee last year by some of our most eminent engineers and manufacturers must have opened the eyes of many to the enormous advantages which would be conferred upon many of our national industries if only the schemes which were proposed were allowed to be carried out. We are informed in unmistakable terms, and facts and figures are at hand to support the view, that if we make proper use of this weapon it will stand us in better stead than perhaps anything else in meeting foreign competition. The Institution of Electrical Engineers has done well to devote one of its sittings to a general consideration of the Electric Power Bills of last session. Mr. W. L. Madgen, who is actively interested in one or more of the schemes, introduced the discussion, and urged upon members of the Institution the necessity that exists for it to present a bold front to everything in the nature of unreasonable restrictive legislation which may be placed in the way of these very necessary means of electrical power development.

Largest Electrical Undertaking in the World.

The conversion of the New York Elevated Railway from steam to electric power will, it is expected, be completed by June next. The magnitude of the undertaking may be guessed from the fact that the system will be the largest of any yet attempted in any country. On two consecutive days of last year the railway carried 1,700,000 passengers, and during the heaviest period of traffic 280 trains, or 1,280 cars, were run per hour, the total for the 24 hours being 4,820 trains, making 43,850 train miles, and 2,189 cars, making 191,390 car miles. The record traffic figure for the system for 24 hours was reached in 1892, when 1,075,000 passengers were carried in one day. The system adopted comprises eight 8,000 h.-p. three-phase Westinghouse generators in a single power station, delivering power at 11,000 volts through three conductor cables, to step-down transformers located in seven sub-stations. These sub-stations are in convenient proximity to the railway lines, and contain 1,500 KW. Westinghouse rotary converters receiving current from the step-down transformers at 390 volts, and delivering continuous current through single conductor cable to the third rail at 625 volts.

FIG. I.—INTERIOR OF A CHURCH CAR ON THE GREAT SIBERIAN RAILWAY.

The Great Siberian Railway.

In making the vast outlay of several hundred million roubles for the construction of the Great Siberian Railway, the Russian Government did not expect in the near future to get a strictly commercial return. Its profit was based on numerous elements of increase in the national economy, conjectural and incapable of arithmetical calculation, connected with the commercial and industrial development of the country. The railway has, however, already exercised such a mighty influence on the growth of economic life in Siberia, that its commercial success far exceeds the most extravagant expectations.

Upon the opening of provisional traffic on the West Siberian Railway in 1895, and of regular traffic in October, 1896, the means at its disposal were far from sufficing for the transport and conveyance of the passengers and goods which presented themselves. In order to obviate this difficulty, 31 sidings were added in 1896—1898 to facilitate the traffic, while the rolling stock was increased by 30 locomotives and 600 carriages. However, during the winter of 1899, 7,000 waggons, carrying over 5,000,000 puds of goods, blocked the line.

The following figures illustrate the increase of passenger and goods traffic:—

The West Siberian Railway conveyed in 1896, 160,000 passengers, 169,000 emigrants, and 10,500,000 puds of various goods; in 1897, 236,000 passen-

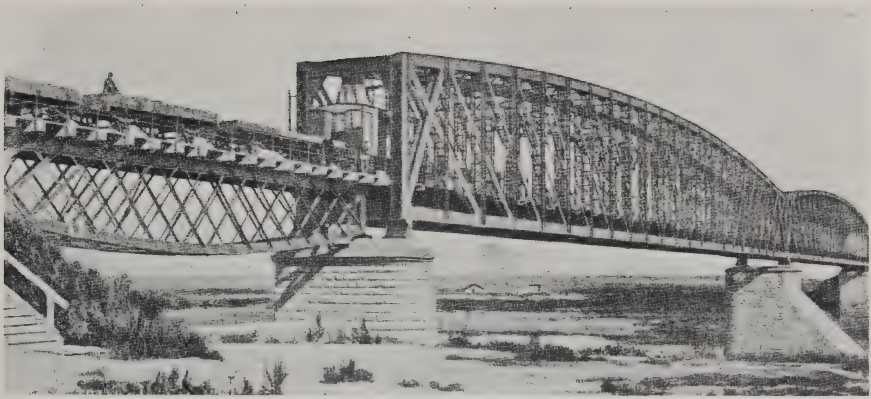


FIG. 2.—BRIDGE OVER THE ISHIM, TYPICAL OF THE BRIDGEWORK ON THE GREAT SIBERIAN RAILWAY.

gers, 78,000 emigrants, and 21,190,000 puds of goods; in 1898, 379,000 passengers, 195,000 emigrants, and 30,000,000 puds of goods.

The Mid-Siberian Railway conveyed in 1897, 177,000 passengers and 5,393,000 puds of goods; in 1898, 476,000 passengers and 11,000,000 puds of goods.

On the West Siberian Railway, which was first opened, the passenger traffic increased by 50 per cent., and the goods traffic by still more.

Further progress in the development of the traffic of the Great Siberian Railway is certain, especially upon the junction of the main line with the port on the Pacific Ocean, when there will be continuous railway communication between Europe and the East of Asia, and there will be created the safest, quickest, cheapest, and most convenient route. Brought into connection with the network of European railways, and running through the Russian empire, this railway mostly traverses cultivated

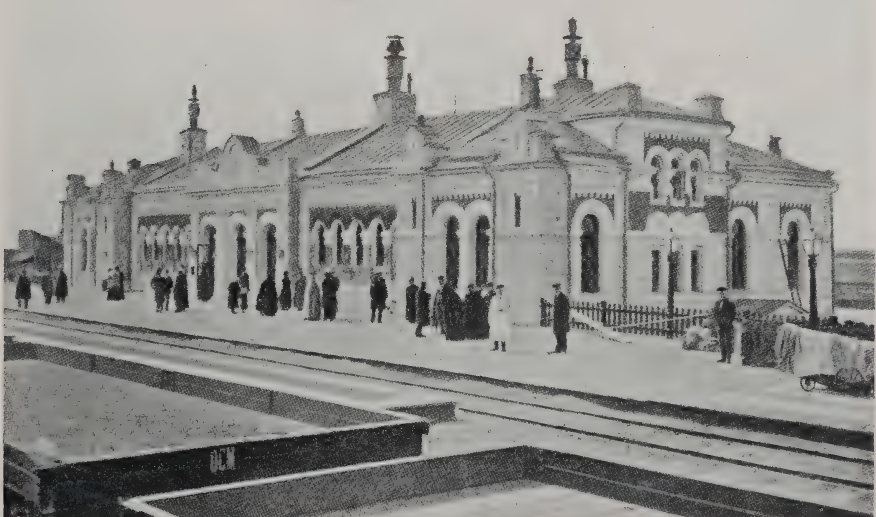


FIG. 3.—THE GREAT SIBERIAN RAILWAY A TYPICAL STATION.

and productive countries, uniting their commercial centres, and offering new outlets and prospects for Russian and international intercourse and trade.

At the present time, Europe communicates with Asia, *viâ* the Suez Canal, by means of four great steamship companies: the Peninsular and Oriental, the Messageries Maritimes, and the German and Austrian Lloyds and the lesser companies; the Russian Steamship and Trading Company, and the Volunteer Fleet. They all work well, but do not suffice to meet the demand for transport.

The journey from London to Shanghai by this railway includes three days from London to Moscow, ten days from Moscow to Vladivostók, three days from Vladivostók to Shanghai, or a total of sixteen days.

FIG. 4.—GOLD-MINING IN SIBERIA.

Conveyance by the Siberian Railway, therefore, will be over twice as quick and two and a half times cheaper than by either of the steamship lines, and by increasing the speed up to that adopted in Europe, the journey from London to Shanghai will be reduced to ten days.

A magnificent work* has just been issued in the English language on this railway, and the figures given herein are taken from it. This volume is of absorbing interest, and besides dealing with the plan and construction of the railway proper, describes and illustrates the country and peoples through which it passes.

* "Guide to the Great Siberian Railway." London: P. S. King & Son. Price 13*s*. Several hundred illustrations.

THE WATER-TUBE BOILER PROBLEM.

IS THE COMMITTEE QUALIFIED?—ITS INTERIM REPORT.

THE nation has followed with the keenest interest the development of the water-tube boiler question, and there is no doubt that the interim report just issued by the Committee will give some satisfaction, insomuch as it condemns the Belleville boiler. Here are the questions put to the Committee by the Lords Commissioners of the Admiralty, and the replies thereto :—

(1.) With the experience and information which have already been obtained, can it be stated whether water-tube boilers are considered by the Committee to be more suitable than cylindrical boilers for naval purposes?

> (1.) The Committee are of opinion that the advantages of water-tube boilers for naval purposes are so great, chiefly from the military point of view, that, provided a satisfactory type of water-tube boiler be adopted, it would be more suitable for use in His Majesty's Navy than the cylindrical type of boiler.

(2.) Should the answer to the above question be in the affirmative, do the Committee consider that the Belleville boiler has such an advantage over other types of water-tube boilers as to lead them to recommend it as that best adapted to the requirement of His Majesty's Navy?

> (2.) The Committee do not consider that the Belleville boiler has any such advantage over other types of water-tube boilers as to lead them to recommend it as the best adapted to the requirements of His Majesty's Navy.

(3.) Generally, having regard to the importance of deciding on the types of boilers to be provided for vessels which are ordered in the immediate future, are the Committee prepared at present to make any recommendation, or to offer any suggestions on the extent to which any particular type or types of boilers should be fitted in new vessels?

> (3.) The Committee recommend :
>
> (*a*) As regards ships which are to be ordered in the future :—That Belleville boilers be not fitted in any case.
>
> (*b*) As regards ships recently ordered, for which the work done on the boilers is not too far advanced :—That Belleville boilers be not fitted.
>
> (*c*) As regards ships under construction, for which the work is so far advanced that any alteration of type of boiler would delay the completion of the ships :—That Belleville boilers be retained.
>
> (*d*) As regards completed ships : That Belleville boilers be retained as fitted.

The report further states that the Committee have had under consideration the Babcock and Willcox, Niclausse, Dürr, and Yarrow boilers, and recommends that if a water-tube boiler is to be decided upon at once for use in the Navy, some or all of these types should be taken, with a view to experiments being carried out with them.

The reasons why the Belleville is condemned are given; but it would be superfluous to repeat them here, as the

objections to this type of boiler have already been made plain in the numerous articles which have appeared in the press for several years past.

It should be mentioned here, however, that one member of the Committee, Mr. J. A. Smith, Inspector of Machinery, R.N., does not wholly concur with his colleagues regarding the Belleville, but he is of opinion that, pending the issue of the final report of the Committee, this boiler should not be included in future designs of war vessels.

It was, of course, a foregone conclusion that the Belleville boiler would be discarded; there was positively no other course open to the Committee. But the most important finding in the report is, "That, provided a satisfactory type of *water-tube boiler* be adopted, it would be more suitable for use in His Majesty's Navy than the cylindrical type of boiler."

Water-tube Boilers are a Necessity.

The adoption of water-tube boilers in war vessels is a natural step in the advance towards a perfect naval fighting machine. There are but few of those who have any expert acquaintance with the subject who are not agreed on this matter. Draught of water and speed are elements even more essential to the success of these vessels than is strength to withstand projectiles, and consequently any saving in weight or space which is connected with efficiency and with the rapid command of great steam power, is of the utmost importance in war vessels. Sir A. J. Durston has made it plain from his results of recent trials of the machinery of warships that the *increase of steam pressure* to 250 and 300 lb. per square inch has had a great influence on economy of weight and space in vessels of the British Navy, and such pressures could not be carried with security to the vessels by boilers of any tank design. In addition to this, rapidity in generating steam is, of itself, even in the absence of other advantages, sufficiently important to justify the selection of the water-tube design, which possesses this qualification as against the older type (as regards the Navy) of tank or drum boilers which does not.

This being the state of affairs, the vital question which the Committee now has to consider is, which water-tube boiler is the best, or how can they be compared and have their relative values estimated?

Is the Committee Qualified?

In an article by the writer which appeared in The Engineering Times a few weeks ago criticising the constitution of the Committee, the statements were made that:—

(1.) With the exception of the naval engineer member, not one member has had any practical experience either of working or of making water-tube boilers of any design.

(2.) All the members, excepting the naval men, have duties which demand their first and close attention, and which they cannot afford to sacrifice in favour of this appointment.

These statements remain unrefuted, and yet, it is believed, no steps are being taken to add to the Committee a few men of sound practical experience, and men who are not already occupying official positions which would interfere with the duties of such an appointment. Some contemporaries, in discussing the article referred to, and defending the constitution of the Committee, go so far as to assert that *practical experience is not a necessary qualification* for a member, and that the truth can be got at without it.

In the popular view, all boilers are pretty much alike because they are called "boilers," and consequently many people think that any engineer who has made one boiler can judge the merits of any design. There could not be a greater mistake.

The boilers formerly in use in the Navy were merely huge kettles, depend-

ing on the thickness of their steel plates for strength to resist pressure, and containing a very large volume of steam ready to escape and of water ready to burst violently into steam the moment any damage was caused to a boiler shell, and in which for many reasons the circulation of water was defective, the formation of steam was slow, and the waste of heat considerable. The water-tube boiler is in no proper sense a kettle: it is (or should be, for we know there are good and bad designs) a scientific steam-generating apparatus, depending for its strength on small diameters, and consequently using thin metal for pressures two or three times (or even ten times) greater than the cylindrical boiler could stand; and, on account of the comparatively small quantity of water which it contains and its larger heating surface, requiring the utmost skill in directing and aiding the rapid movement of both the water and the heating gases. The thinness of the metal forming it also demands every condition favourable to preservation. It is at once apparent that the old practice, as well as the old designs, cannot apply to this new state of matters. Of old, a boiler was filled up with water, coal was shovelled into the furnaces, and the water and hot gases were left to do very much as they pleased so long as the steam collected in the upper part of the boiler and the smoke went up the chimney. That happy-go-lucky way will not answer now, and a water-tube boiler to be successful must in its construction and method of working adhere to rigid principles of physical science, its success being commensurate with the degree in which these are practised, just as they form the criterion by which it must be tested and judged. The construction and working of cylindrical boilers is therefore no adequate preparation for the investigation of the water-tube boiler question, and it is precisely this fact which makes the objection to the limited character of Mr. Goschen's Boiler Committee a fatal one for that Committee. How are men, lacking experience in the working and building of water-tube boilers for marine purposes, to tell us which is the most suitable boiler for our Navy?

Not one word can be said against the excellence, in their own spheres of action, of those who were originally appointed; but it is evident that as so constituted the Committee lacks the element of expert knowledge which it undoubtedly ought to possess, if its opinions on the future water-tube boiler for our Navy are to be of any real value.

What was Mr. Goschen's Idea?

Mr. Goschen's idea may have been that, by excluding all engineers who were in any way associated with water-tube boilers, the Committee would avoid influence in favour of any special design, and would be able to give an unbiassed judgment on all designs. But, if so, he only showed therein the ordinary layman's erroneous view which confounds all apparatus to which the name "boiler" is applied.

It is to be hoped that Lord Selborne will see that this is not a satisfactory foundation for such a body, or likely to give its opinion a passport to the respect of the intelligent section of the public, and that the existing defects in the constitution of this Committee will be soon remedied by the addition of a few men of sound practical experience.

THE PLACE OF SCIENCE IN EDUCATION.*

By Dr. HENRY T. BOVEY, Pres. Canadian Society of Civil Engineers.

ENGINEERING is a term which has been chosen for its general usefulness, and has been applied to so many things that it is difficult to seize its essential characteristic. It so happens that certain investigations into the chemical and physical properties of matter, into the dynamics of steam, electricity, etc., have been made by the engineer rather than by the physicist and the chemist because these investigations have been required by the practical work of the engineer, and because they have sometimes to be carried out on a scale inconsistent with the more delicate experiments which are the chief occupation of a physical laboratory. So it has come to pass, as a matter of convenience mainly, that engineering, besides being a profession, has been made directly responsible for certain scientific work, and may in this light be looked upon as in itself a science. Further, perhaps, as its proper training seems to involve a considerable acquaintance with mathematics, as well as with one or more of the natural sciences, of which I have spoken, the study of engineering in general may be considered as synonymous with the study of a particular combination of sciences, joined together with a view to a direct practical result. A special application of this statement will be spoken of later, but in the meantime it will be sufficient for our purpose to recognise that engineering, so far as it affects education, is to be grouped with the sciences, and that what may be said of them may be said of engineering. It has certainly been the needs of my own profession which have caused me to give so much attention to the effect of a scientific training upon the minds of young men, and to the best methods of securing its advantages.

So much has already been said and written on this subject that it seems at first as if all must have been said that could be said. Until, however, we have exhausted the records of experience, and until we have been able to map out the human mind—scientifically, of course—there will still be much to learn on this as on every other educational subject, and if I am able to contribute nothing new, one never knows when a new idea may be struck out from the discussion of old ones, as a spark from the rubbing together of cold flints.

I may say at the outset that I am no advocate of an exclusively scientific training. Boys of thirteen and fourteen—and their parents—are often obliged to choose between what are called the scientific and classical sides in a school. This I believe to be a distinct evil, though it is sometimes a necessary evil. The general or all-round education of the boy should be continued as long as possible, and it should still be open to him on entering the university to choose either a literary or a scientific career. These conclusions I consider to be based upon the mental constitution of all ordinary boys; I do not here speak of the genius. How can

* Extract from Presidential Address.

a schoolboy have a sufficient knowledge of himself or the world to recognize his true relation to his environment, and few parents, indeed, can so discern the fruit in the bud as to be able to decide what specialized course of training would be best suited to their sons. In every boy's life there comes a time—sometimes late and sometimes early—when he naturally reaches out into the future and considers, with more or less seriousness, according to his temperament, his relation to the world. Then, and not till then, can much value be attached to his instinctive leaning to one path or another. The choice once made should be persevered in; there should be no turning back when the hand has been put to the plough.

Nor need it be imagined that young men are losing time when not directly preparing for some special sphere, for, in the opinion of many educators, the best training for a special sphere is that which will give the mind the largest grasp of which it is capable. What part science should play in this is the question I would, with your permission, more particularly discuss.

It may be interesting to notice some recent definitions of the term "science." In the first place, science should be distinguished from knowledge. Quoting from the words of a well-known writer, "Knowledge of literature, of the beautiful things which have been written or otherwise produced by human ingenuity, is not science. Knowledge of the various manufacturing processes in use by civilized men is not science; nor knowledge of the names of the stars, or of the joints of a beetle's leg. Science cannot be identified with knowledge of any particular class of objects, however detailed that knowledge may be. It is a common mistake to consider all knowledge of raw products, of living objects, or other natural objects, as necessarily 'science.' The truth is, that a man may have great knowledge of these things as so many facts, and yet be devoid of 'science.' The mere knowledge, then, of any fact is not science. Science, again, is not to be confounded with invention—or its applications. It is of the utmost importance for the progress and well-being of science that this should be understood; that the eager, practical spirit of the inventor who gains large pecuniary rewards by the sale of his inventions should not be confounded with what is totally different and remote from it, namely, the devoted, searching spirit of science, which, heedless of pecuniary rewards, ever faces nature with a single purpose—to ascertain the causes of things."

Science, then, seems to be applied properly to our knowledge of the facts of the world in their relation to one another; above all, in their relation to cause and effect. An isolated fact even about nature may be called knowledge, but cannot be rightly called science until we have fitted it to some other fact,—until we have done something towards recognizing its place in the great order of the universe.

> "That orbed maiden, with white fire laden,
> Whom mortals call the moon,"

is poetry, but when we ask the source of the "white fire," and trace it to the luminous corona of the sun, or when we ask how it reaches our senses, and how it excites the nerve of sight, we have left poetry—we have entered the territory of Science.

Now, what does this science do for us that should give it the right to enter as it is doing the domain of education? We may say, perhaps, putting the answer in its most general form, science makes us understand our material environment, which, if not our highest environment, is the absolutely essential medium through which our highest is known. It sets open for us doors on all sides. We can

peer into the rifts of the rocks, and see, with Ruskin, how the quartz has been interlacing them with crystal threads; we can follow the flight of the winged seeds of the plants, can tell how these spread their rootlets in darkness and yet reach ever up to the light; we can trace out the family-trees of the birds and beasts; can turn our microscope on a drop of water and see into a world full of its own forms of life; can trace out our path among the stars, or our ceaseless journey into and out of the sunlight.

> "World of my life,
> Swing thee round thy sunny track,
> Fire and wind and water and strife,
> Carry them all to the glory back."

Through most of these doors we can take but a glance, but it is one of those potential glances which do not leave us where we were before.

> "Conceive, then, earth's resources! Vast
> Exhaustless beauty, endless change of
> wonder!"

Our nature follows a law, like that of the diffusion of gases. Open the door, and forth it will pass to take possession of the new realm of knowledge.

If science gives us a knowledge of the world we live in, the *scientific method* goes far to settle the other half of the problem of our physical life, and by training our faculties, mental and moral, to fit us for that world.

It is no small compliment to science that in almost every study we hear of the application to that study of the scientific method. Great thinkers have written of the science of history, of the science of grammar, of the science of language. What does this mean? What is this process which is considered so desirable?

The scientific method proceeds by way of observation, analysis, classification, generalization, deduction and experiment, names in some cases common to the processes and to the faculties by which they are carried out, as when we speak of a man's observations, and say, in the same breath, that he is a man of keen observation. This rather confusing language hints at the fact of the living relationship which exists between the two, so that no observation can be made without presupposing a faculty for it, and no faculty can be cultivated in any other manner than by using it. The importance of the faculties referred to can hardly be over-estimated, and is being steadily more and more recognized on all sides. In the present war we have a most striking example of this. Has not each writer, in his own way, tried to impress us with the absolute necessity of using every sense and every faculty in war? What is General Baden Powell's "Aids to Scouting" but a plea that special attention should be given, either by oneself or others, to the cultivation of those powers which necessity has often called out in the uneducated?

Of the keenness of observation shown by Indians we have hundreds of stories. I may instance two which have been told to myself. The late Dr. Beers, who gave so much thought to the welfare of the Indians, told me of one who came into his office and there saw an engraving which struck his fancy. He looked at it for a few minutes, then went away, and a few weeks afterwards sent back a painted reproduction, which bore a very remarkable resemblance to the original.

Again, a friend of mine, having occasion to pass two or three times along a road of perhaps several miles in length, through a forest, made a cache on the way, to prevent the necessity of carrying so much baggage. On the return journey the Indian guide stopped on the monotonous road, took a few steps to one side and drew out the hidden store, although a snow-storm in the meanwhile had completely obliterated every mark by which the place might have been known, to the ordinary observer. Could our

Senior Classics or our Senior Wranglers rival this performance? I fear not yet, but this power of observation is the first lesson scientific education is trying to teach, and with no small amount of success.

The way in which our vaunted knowledge, combined with what appears to him ridiculous ignorance of our surroundings, strikes the savage, is amusingly illustrated in the opinions held by certain Indians of the North-West. Reasoning from the helplessness of the amateur hunter and ordinary traveller in distinguishing the natural signs and sounds in the woods, they designate the white man as "the foolish man." Being asked by the missionaries why they do not go to church, they answer, "We have been there, and have heard what you have to tell us, therefore we know it, and do not need to come and hear it a second time. The white man has to be told the same thing so often that he must always have his book tied to him."

Count Rumford points out how much the cause of science in general is likely to profit by the continual use of the seeing power which is the first process of the scientific method. He says:—"I am persuaded that a habit of keeping the eyes open to everything that is going on in the ordinary course of the business of life has oftener led, as it were by accident, or by the playful excursions of the imagination put into action by contemplating the most common appearances, to useful doubts, and sensible schemes for investigation and improvement, than all the more intense meditations of philosophers, in the hours expressly set apart for study."

He himself hit on the true explanation of what becomes of work spent in friction, when superintending the boring of cannon in the Arsenal workshops at Munich.

No doubt to achieve such a result as this, observations must be of a special character. They should be minute, like those of Hunter, in his study of the deer's horns; they should be accurate, like those which led Adams and Leverrier to the simultaneous discovery of Neptune, and, above all, they should be selective—*i.e.*, if we are following up a special point, we should be trained to fasten, as it were, on the fact which throws light on the question at issue, remembering that it is not always, or even usually, the prominent feature which will put us on the track of a discovery of true connections, but more often some small point, which the ordinary person passes by unheeded.

On one occasion, the Doctor, from whom Sherlock Holmes' picture was drawn, commiserated a complete stranger on having taken such a long walk that morning, and, seeing his look of surprise, explained in a matter-of-fact tone that there was no place within five miles where he could have got that splash of red mud upon his boot. The simplicity of the explanation when we know it does not make it the less remarkable.

And so with the other processes of the scientific method. Take analysis—which has sometimes to accompany observation. Its importance is seen when we reflect that objects in nature do not appear to us, as a rule, classified and docketed as they do in text-books; in fact, the study of nature is oftener like reading a text-book backwards. "You study Nature in the house, and when you go out of doors you cannot find her."

Without classification, again, we cannot be truly scientific, keeping to the definition that we have chosen for science, for it is by this process that we fit observed facts into their proper place as it were, gathering up the new with the old into a larger synthesis.

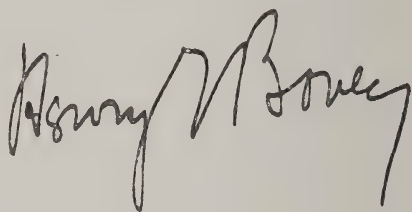
Further, the necessity of carrying out of experiments has produced in many men a remarkable development of resourcefulness.

Wollaston, who was the first to demonstrate the identity of Galvanism and Electricity, when asked by a distinguished foreigner to show him his laboratory, immediately brought out a small tray containing a few glass tubes and a blowpipe. Elaborate apparatus were needless to him, as to most geniuses.

Naismith, too, was a fine example of resourcefulness, though, perhaps, he did not get his faculty from his scientific training, but came by it naturally, as it is related of his father, that, once being anxious to go to the Ranelagh, at which striped stockings were considered an essential, he himself washed his only pair, and set them in front of the fire to dry. The story goes on to say, that finding, when the time had arrived, that his stockings were reduced to a cinder, he repaired the damage, nothing daunted, and that his stockings were the envy of the room,—he had painted his legs.

What incessant call there is in all this for eager attention, concentration of mind, clearness of judgment, etc.! Indeed, in working out this scientific method, which I have tried to put before you,—this process of observation, analysis, comparison, judgment, synthesis, deduction, experiment,—we shall find that nearly all the mental faculties, and not a few moral qualities, are brought into play.

(*To be continued.*)



SOME ANCIENT AND MODERN TRACTION ENGINES.

By W. FLETCHER, M.I.Mech.E.,

Author of "Steam Locomotion on Common Roads," etc.

INTRODUCTORY.

THE early history of traction engines has been little more than a recital of failures. If the trial trips of some of the early specimens were written they would be very amusing. The first road engine ever made sadly misbehaved itself by knocking down a wall that happened to be in its way, and soon afterwards the same engine fell on its side with a crash while turning a sharp corner in the streets of Paris, for which untoward offence the engine and its maker were at once locked up in prison to prevent them from doing further mischief. Since Cugnot's little top-heavy pioneer tumbled over, many others have evinced a desire to follow its example.

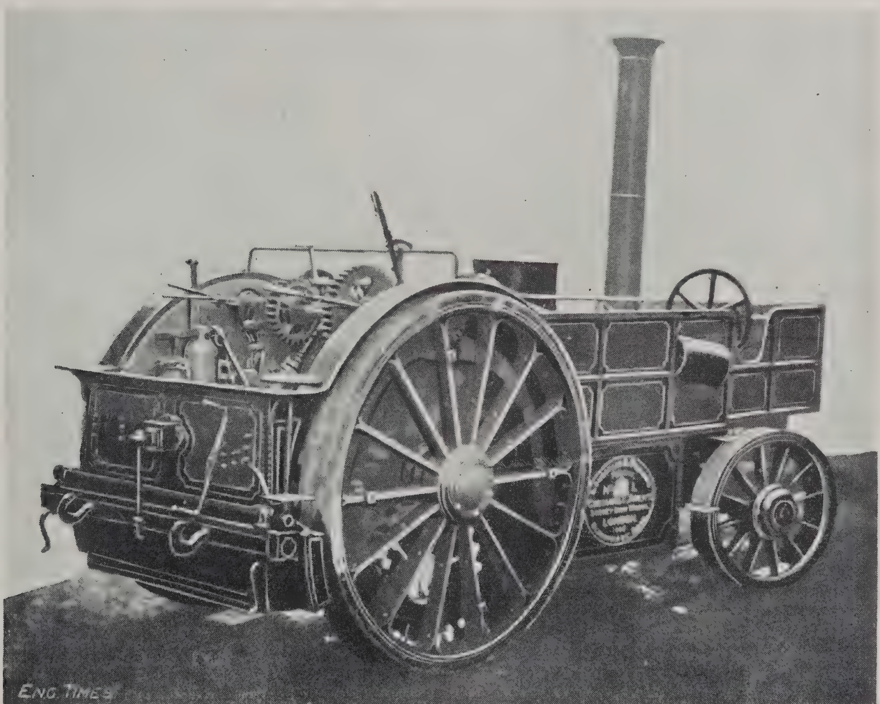


FIG. I.—LONGSTAFF AND PULLAN'S ROAD LOCOMOTIVE.

It is quite true that many inventors during all the periods of the traction

engine's history have patented and constructed all sorts of abominable abortions in the way of steam locomotives for common roads. Dozens of these impossible schemes have never seen the light, others have been made for a very brief day and a sudden termination. The twentieth century patent journal unmistakably shows that even now "Fools rush in where angels fear to tread."

Few firms have introduced their first traction engine without some mishap. In some cases failure after failure has occurred previous to the perfecting of their number one; gratifying results were reported during the trial, but, curiously, no second engine was ever built on the same lines. The first traction engines made by two or three firms were never delivered to customers. One at least never emerged from the factory. The earliest performance on the road took place in a dark corner of the yard, and was of too novel a character to admit of a repetition. Consequently, those few persons who viewed the excentric gyrations of the number one may consider themselves favoured, seeing that as soon as the performance was concluded, the engine was consigned to a dark corner of the shop and forgotten, or the boiler was stripped and some of the parts were utilised for other purposes. The shop engines of two firms were supplied with steam generated by traction engine boilers, which were never allowed to leave the maker's hands.

An early traction engine, which rejoiced in the name of "The Little Hero," went for its first quiet walk, when some vital detail gave way causing a complete breakdown. After various unsuccessful attempts at rough repairs on the spot had been made, the engine was dragged home by a team of horses. Some days afterwards it was sent on a second trial, when serious results developed from a totally unexpected quarter, causing the engine's partial disablement. It was steamed home with difficulty. In its next outing it proved itself well adapted for digging holes in the road. It rapidly excavated a couple of holes, and was about to rest itself comfortably in them, when further boring operations were unceremoniously stopped. All frantic attempts, however, failed to avert the latest catastrophe; the engine mined a gap in the earth and half buried itself. It was now all but left in hopeless disgust. Two or three festive days were spent by a gang of men with screw-jacks, planks, spuds, and other interesting appliances, when the "Hero" was raised to a dignified position once more. But the engine's character was so damaged by these disgraceful proceedings, that the "Hero" was returned to the works, from which it never emerged. We could give a list of festive experiences and some mournful days spent in trying the early traction engines of many firms in various parts of the country, but we must now illustrate some of the engines themselves, and, judging by the grotesque appearance of the ancient ones, we need not wonder at their ungainly performances at work.

HISTORICAL EXAMPLES.

In the small amount of space placed at our disposal, we can only glance at some of the early types of engines, but we hope to pay more attention to the latest and best traction engines of the day. Sixty years ago, Nathan Gough, of Salford, made a road locomotive for drawing heavy loads at a moderate speed, and this traction engine, made as far back as 1830, was the prototype of the thousands of engines which have followed. No particulars appear to have been preserved of Gough's engines, but a few persons now living remember to have seen one of them on the roads near Manchester.

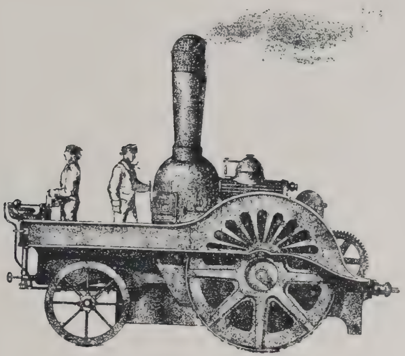


FIG. 2.—TAYLOR'S "STEAM ELEPHANT."

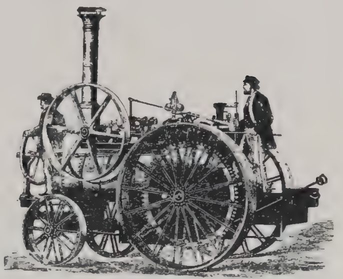


FIG. 3.—RICHARDSON AND DARLEY'S LOCOMOTIVE.

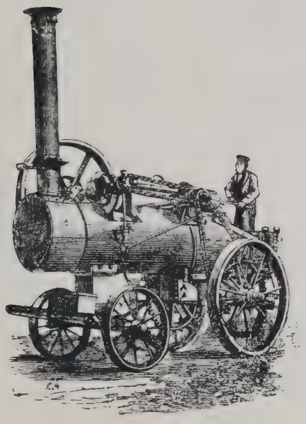


FIG 4.—BRIGGS' ENGINE.

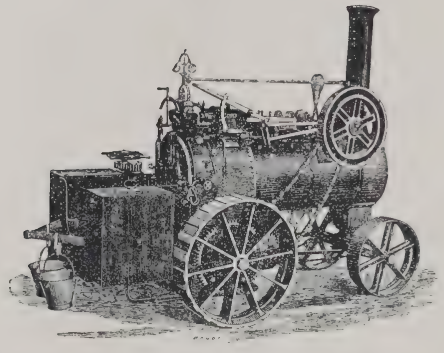


FIG. 5.—NICHOLS' SELF-MOVING ENGINE.

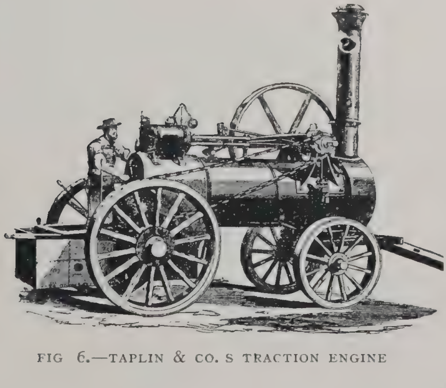


FIG 6.—TAPLIN & CO. S TRACTION ENGINE

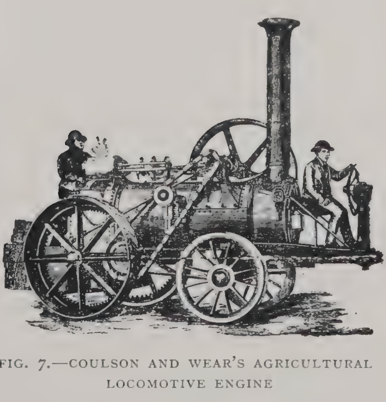


FIG. 7.—COULSON AND WEAR'S AGRICULTURAL LOCOMOTIVE ENGINE

EARLY TYPES OF ROAD LOCOMCTIVES.

In 1858, Messrs. Longstaff and Pullan made a road locomotive which attracted considerable attention ; it is shown by Fig. 1.

This traction engine possessed one or two important features which should be named in passing. The whole of the bearings for the shafts and axle were carried at the fire-box end by two strong side plates, very much in the same manner that is now adopted, but these side plates were also hung on springs. In one arrangement the axle and shafts were all in one vertical line. The second feature about this engine of 1859 is that a considerable portion of the spur gearing was placed between the horn plates inside the bearings. On a model of this engine which has been exhibited in the Patent Office Museum since 1862, the fast and slow pinions were keyed to the crankshaft, and the double spur wheels on the countershaft were made to slide into gear in the same manner as is now the common practice. In another engine designed by Longstaff and Pullan, the two pinions for giving the different speeds were keyed at opposite ends of the crank-shaft. The wheels on the countershaft were each slid into gear by a screw clutch and hand wheel, and both the pinions on the crankshaft and wheels on the countershaft were placed between the brackets above the boiler. It will thus be seen that inside gearing is no recent production, but was used as far back as 1859. We may say that this engine was made by Gardiner and Mackintosh.

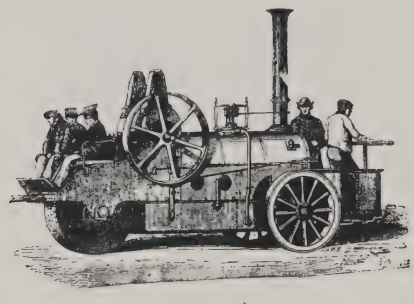


FIG. 8.—TUXFORD AND SONS' ROAD LOCOMOTIVE.

Mr. Taylor, of Birkenhead, constructed a number of powerful road locomotives which he termed "steam elephants." Fig. 2 shows one of these engines made in 1859. Messrs. Richardson and Darley turned out in 1862 a remarkable traction engine, as illustrated by Fig. 3. The design of this engine was very good when compared with many engines for road work at that date. No driving chains were used ; the countershaft had a pinion at one end which geared into a large spur ring bolted to the spokes of the large driving wheel, which was evidently made of wrought iron, having two rows of spokes. The engine parts were bolted to a channel frame on the top of the boiler. Fig. 4 represents a wonderful relic, which was made by Mr. Briggs, of St. Ives. It was a transformed portable engine ; a pitch chain from a chain pinion on the crankshaft transmitted motion to a countershaft fixed in front of the cylinder. This countershaft drove the hind wheels by means of chains, as shown. The next illustration is another transformed portable engine. Fig. 5 was made by Mr. Nichols, whose experience we are told extended over thirty years making these traction engines. Messrs. Taplin & Co.'s self-moving engine, as shown by Fig. 6,

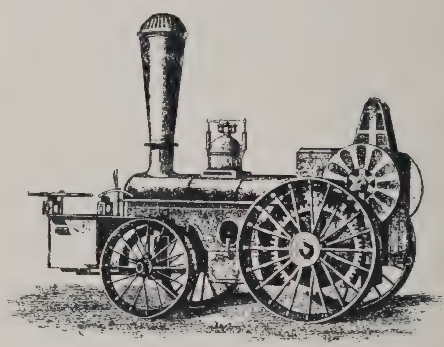


FIG. 9.—TUXFORD'S PATENT FOUR-WHEEL ENGINE.

was made in 1861; it required a horse in the shafts to steer it. Another early traction engine is shown by Fig. 7; it was made by Messrs. Coulson and Wear; the boiler was tested to a pressure of 200 lb. per square inch. The driving wheels were made of wrought or cast iron as required. In a later engine of this maker the driver and the steersman were both stationed on the footplate behind. Messrs. Tuxford & Sons' patent steam road locomotive is next illustrated by Fig. 8. A prize medal was awarded to this engine at the 1862 Exhibition for good design and good workmanship. The engine was furnished with two cylinders, which together with the whole of the working parts were enclosed in an iron house at the end of the boiler. Motion was communicated to the driving wheels by means of spur gearing in preference to pitch chains. Two travelling speeds were provided. The engine was fitted with compensating gear, and travelled fire-box foremost, a return flue boiler being used so that the chimney was at the fire-box end as shown. Messrs. Tuxford drove the "iron house" portable and traction engine "hobby" to death, and practically killed their trade in this industry. A later Tuxford engine is shown by Fig. 9. Mr. Underhill was "assured that his improved traction engine was far in advance of any ever brought before the notice of the public." He said the novel construction of the driving wheels with zigzag tyres (as shown by Figs. 10 and 11) enabled the engine to travel "through all localities, on arable or turf land"; consequently great things were expected from it as a traction engine. We fear Mr. Underhill's assurances came to nothing; the engine was made in 1865, and appears to us as the most unlikely traction engine to perform the "great things" that were expected from it. In 1866 Messrs. Chaplin & Co. made a road locomotive of the type shown by Fig. 12. As it differed from all

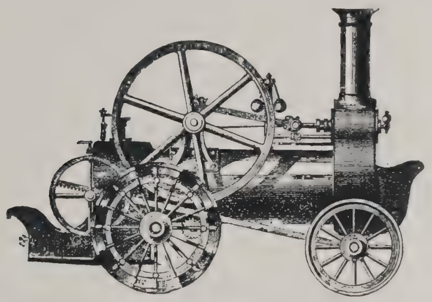


FIG. 10.—UNDERHILL'S PATENT TRACTION ENGINE.

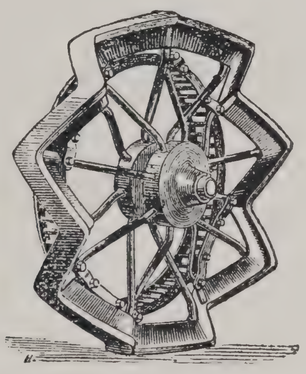


FIG. 11.—UNDERHILL'S PATENT WHEEL

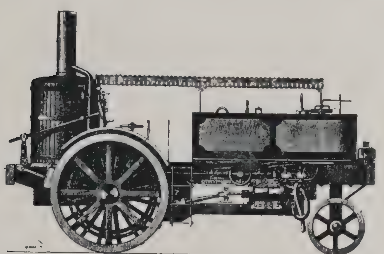


FIG. 12.—CHAPLIN & CO.'S TRACTION ENGINE.

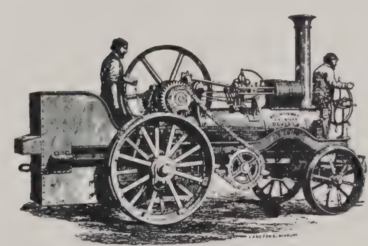


FIG. 13.—AN EARLY TYPE BY BROWN AND MAY

the engines we have so far illustrated, we will give a few particulars of it. The carriage of the engine consisted of a pair of solid wrought-iron frame plates, connected by cross girders, attached to them by corner pieces and turned bolts. The cylinders were let into the openings, and were furnished with flanges above and below as shown. Three sets of gearing between the crankshaft and the countershaft enabled the engine to travel at three different speeds on the road, 2, 4 or 8 miles an hour, according to the duty which it had to perform. At each end of the countershaft a pinion was keyed on, which geared into internal spur rings bolted to the driving wheels. The driving wheels were constructed on Bray's patent plan, and were made of cast iron 6 ft. diameter; they were each fitted with 16 spades, worked by means of connecting rods coupled to a brass excentric strap. By shifting the excentric upon which the strap worked, the spades could be made to project through the rim of the wheel. The engine was mounted upon springs. An upright boiler was mounted in the frame nearly over the driving axle; it was fitted with hanging tubes welded at the bottom ends. The advantage of a vertical boiler for this purpose arises from the fact that the water level is little disturbed by the inclination of the road. The weight of the engine was 12 tons. It was tested in Glasgow by drawing marine boilers weighing 30 to 40 tons. On one occasion the engine hauled a small iron vessel weighing, with the truck upon which it was carried, about 45 tons, a distance of two miles over ordinary paved streets, mounting in the course of its journey an incline of 1 in 30. In those days such a performance was very satisfactory. About this time a number of engines were made by Messrs. Brown and May resembling the illustration Fig. 13; the steam jacketed cylinder was placed near the chimney, the engine was placed upon springs. The engine was fitted with two travelling speeds, one set of gearing having a ratio of 22 to 1, and the fast speed ratio being 11 to 1. An arrangement was made at the countershaft end for taking up the slack in the driving chains. The engine shown by Fig. 14 was a well-made article. We believe Messrs. Robey & Co. were the first to use wrought-iron crankshaft brackets of the type shown, which are so largely used for portable and traction engines now.

The self-moving engine illustrated by Fig. 15 was made by Messrs. R. Garrett and Sons in 1869. Ten years previous to this date Messrs. Garrett made a number of self-propelling engines. They refer to them as follows:—" R. G. and Sons have rendered their ordinary portable engines locomotive by means of an improved self-propelling gear, which can be attached to any portable engine; it does not render the engine complicated. By means of this improved gear an eight-horse portable engine (with one horse in the shafts for the purpose of steering) will propel itself and draw a thrashing-machine behind it over ordinary farm roads."

Fig. 16 shows another of Messrs. Tuxford's traction engines which was exhibited at the Wolverhampton Show, 1871. The engine is placed on the boiler, and not housed in a box as previously illustrated. A wrought-iron frame carried the countershaft and axle beneath the barrel of the boiler; the frame was mounted on spiral springs. The leading wheels were also provided with springs, in the boxes shown. The showyard at Wolverhampton was the scene of some curious experiences with traction engines, as will be gathered from the next illustration.

Fig. 17 shows one of Thompson's road steamers being pulled out of the

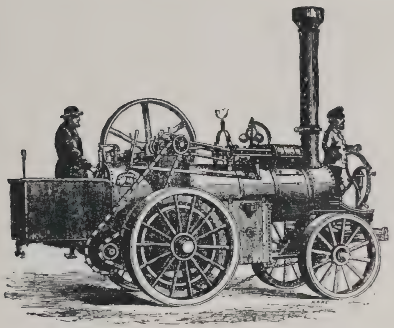


FIG. 14.—ROBEY'S PATENT TRACTION ENGINE.

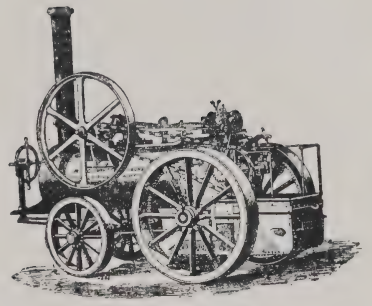


FIG. 15. ONE OF RICHARD GARRETT AND SONS' EARLY ENGINES.

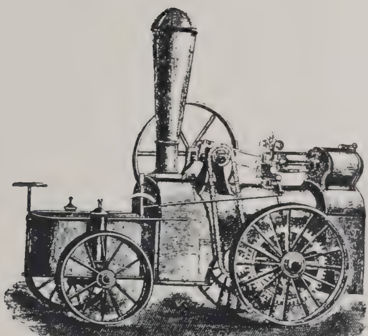


FIG. 16.—TUXFORD AND SONS' TRACTION ENGINE.

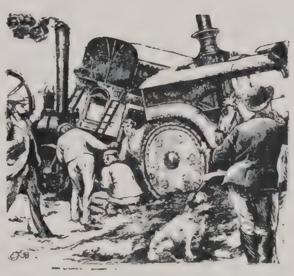


FIG 17.--A ROAD STEAMER IN DIFFICULTIES.

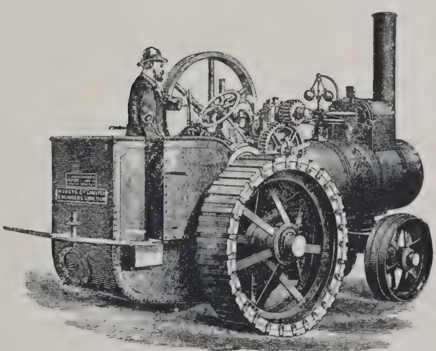


FIG. 18.—ENGINE FITTED WITH MACKINDER'S PATENT WHEELS

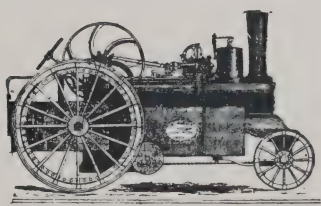


FIG. 19.—JACKSON'S TRACTION ENGINE.

HISTORICAL TRACTION ENGINES.

mud by another traction engine.* The indiarubber tyres were being tried under all sorts of circumstances, and in many instances they were found wanting. We have dealt with the indiarubber and pot-boiler mania of 1871 in another place, so we cannot refer to it here.†

We now illustrate, by Fig. 18, a traction engine made by Messrs. Robey & Co., fitted with Mackinder's patent spring driving wheels. "The patentee worked this engine on his estate for several months, during which time he did all the ploughing and thrashing with it. It conveyed all the farm produce to Lincoln—a distance of four miles—taking back coal or manures on the return journey. As a result of this practical test, the patentee found that this farm engine enabled him to dispense with six horses and two men."

The last engine we shall illustrate in this article is the one shown by Fig. 19, made by F. W. Jackson, Ball's Pond, London, N. We will allow the maker to describe this engine:—"The pitch chain and spur gear, which are a source of continual annoyance owing to their non-reliability, have been abandoned. Two steel tooth wheels of circular steel bars, in direct communication with the road wheels, are employed, both wheels being geared or worked separately, as may be required, by means of friction clutches, either being thrown in or out of gear when the engine is in motion. This gear admits of the rise and fall of the axle, which is supported on springs, without the risk of breaking the cogs of the gearing." The inventor would experience a little difficulty in his arrangement of the driving gear on the flywheel side; the pinion or the wheel would be very much overhung.

As a considerable number of the early traction engines were propelled by pitch chains, it may not be amiss to name the advantages which some of the old-time traction engines possessed, which are not always possessed by modern engines. The advantages of driving by means of pitch chains are briefly enumerated thus:—(1) Simplicity of construction; (2) much less weight; (3) springs can be easily applied; (4) reduced expense for repairs and fewer breakages; (5) noise is suppressed.

1. Simplicity of construction is more easily obtained, the number of shafts and details being reduced in the neighbourhood of the boiler front; the mud-holes at the corners of the fire-box are easily accessible, there being no spur wheels or splashers in the way of them.

2. It is well known by all users of chain traction engines that most, if not all, the details may be made much lighter than those adopted for spur-geared engines. In the place of the heavy gearing and driving discs, the two pitch chains drive on to a light chain wheel on each side of the engine; these chain wheels are secured near the tyre of the driving wheels. By this arrangement the driving wheels, axle, and axle bearings are much lighter than is possible with modern spur-geared engines.

3. The adoption of springs is always recommended. Many plans have been patented for hanging spur-geared engines on springs; many of the designs have ended in failure, and very few are perfectly satisfactory. All these difficulties vanish when chains are used, and the much sought for and very desirable springs can be easily applied in the most simple and convenient manner possible.

4. By the use of springs the wear and tear of the working parts is much reduced; but quite apart from the advantage gained from the springs, many chain engines have cost from

* We are indebted to *The Graphic* for this illustration.

† "Steam Locomotion on Common Roads." 1891. E. and F. N. Spon.

25 to 30 per cent. less for repairs than those needed for heavier geared engines. The breakages are infrequent, and those which do occur are of a trivial nature, and soon put to rights.

5. The crowning virtue of the pitch chains is their noiselessness, compared with the ringing spur gearing; the chains and the springs combined cause the engine to run along smoothly, with more comfort to the driver, and less annoyance to the public generally. We have advanced these remarks because driving chains are being used in light road vehicles, and we feel sure that chains might be adopted for some purposes now with advantage, where the bridges will not bear heavy weights, or in the fen districts, and for Colonial purposes. We have far better machinery for the manufacture of chains than our predecessors had, and we have better types of chains also.

We have omitted to name a considerable number of ancient traction engines because they have recently appeared in connection with another article by the writer. The subject is far from being exhausted. In future articles we hope to deal with the oldest and newest traction engines of the best makers of the day.

(To be continued.)

W. Fletcher.

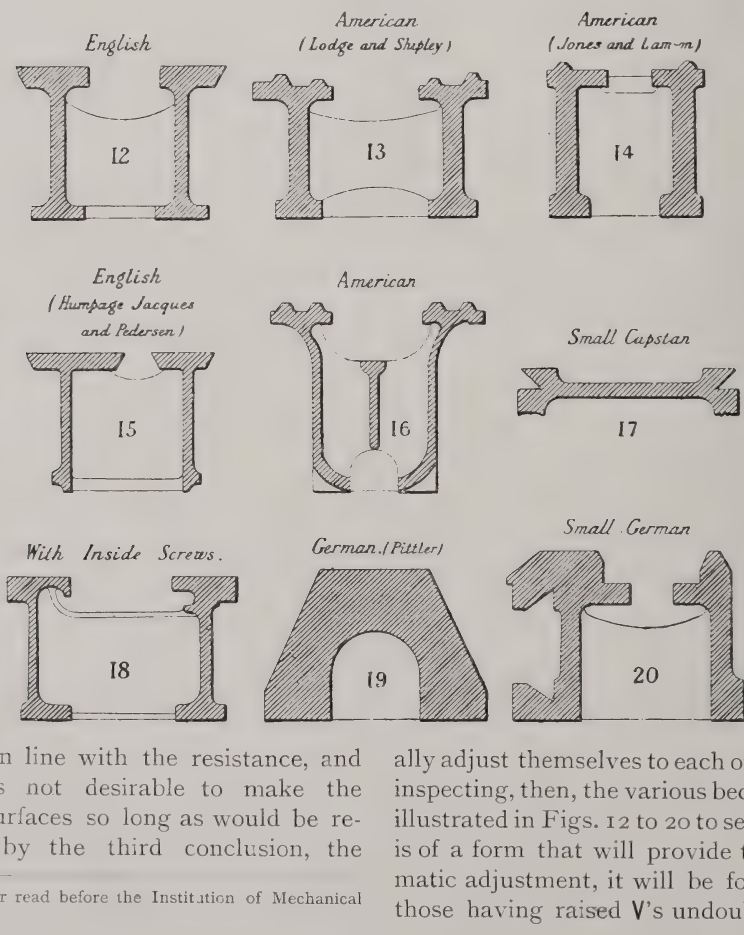
LIGHT LATHES AND SCREW MACHINES.*

By JOHN ASHFORD, A.M.I.Mech.E.

(*Continued from page* 177.)

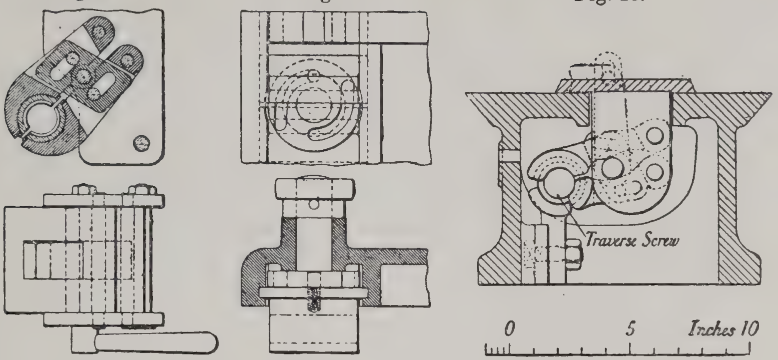
NOW, as regards the shape of the slide-ways of the bed, how do the above conclusions affect their form? As it is impossible to apply the traversing force to the saddle in line with the resistance, and as it is not desirable to make the guide surfaces so long as would be required by the third conclusion, the second should be considered more closely. That the saddle may have no tendency to twist under the action of the traversing force, this conclusion requires that the guide surfaces shall automatically adjust themselves to each other. On inspecting, then, the various bed-sections illustrated in Figs. 12 to 20 to see if either is of a form that will provide this automatic adjustment, it will be found that those having raised V's undoubtedly do

Figs. 12–20.



* A Paper read before the Institution of Mechanical Engineers.

Fig. 21. Fig. 22. Fig. 23.



RELEASE-NUT CLUTCHES.

so, for gravity acts as a closing force, keeping the surfaces in contact.

Considering the remaining conditions (2), (3), (4), and (5), as affecting bed-sections, condition (2) requires protection from dirt. A shape which affords the least facility for catching dirt, or more especially metal particles, which would work in between the rubbing surfaces, causing rapid wear, is one having a sloping surface, such as those in Figs. 13, 14, and 16. The possibility of satisfying condition (3) follows on a fulfilment of (4), provided that there are ample means for the continuous application of oil, which is rarely the case.

English lathe builders pride themselves upon the ample surface supporting the saddle as obtained by the shape in Fig. 12, which is lost by the use of raised V's. No doubt such a form has the very decided advantage of giving direct support to the saddle and reducing spring to a minimum. The great disadvantage of the raised V form, as in Figs. 13 and 16, is the lack of support rather troublesome to put into and out for the saddle immediately under the

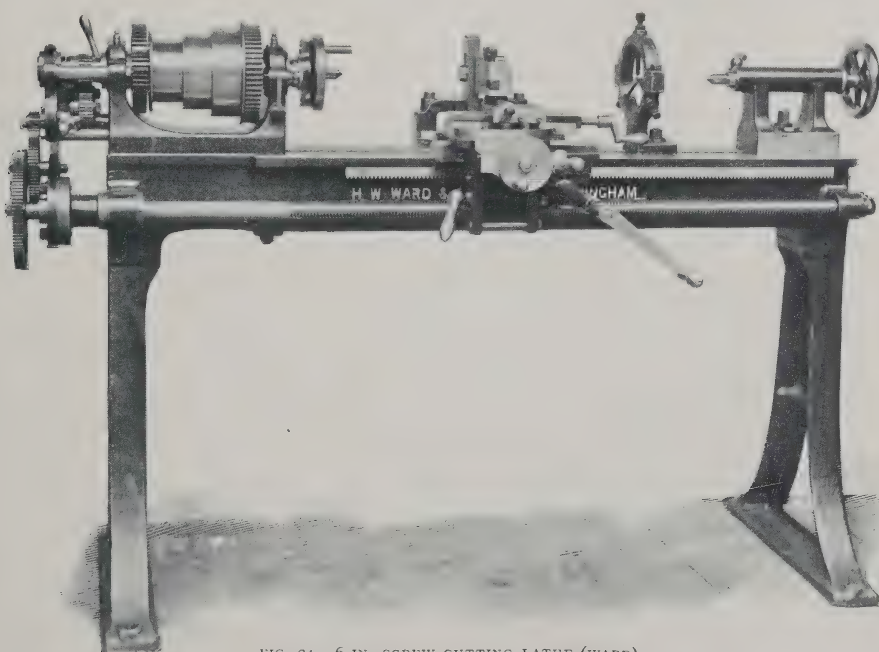


FIG. 24.—6 IN. SCREW CUTTING LATHE (WARD).

tool-rest. The saddle fits upon the two outer V's, and thus has a long span, so tending to make it weak in the back and lacking in stiffness. If, however, the inner V's are placed at a lower level, it allows of an increased thickness in the saddle, which tends to minimise this disadvantage. Moreover, if the cross slide-way is raised upon the saddle, instead of sunk into it, the slide which fits upon it may be of greater length, thus giving a better distribution of the

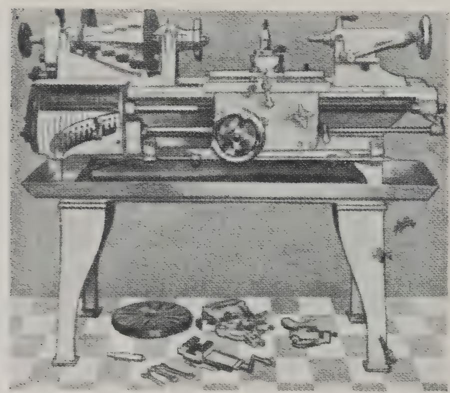


FIG. 25.—6 IN. LATHE WITH SPECIAL CHANGE GEAR.

pressure from the tool when cutting, so adding to the stiffness. Such an arrangement has the further advantage of protecting the cross slide-way from metal cuttings. Ample support for the saddle is desirable, but broad flat slide-surfaces on the bed are not unmixed blessings, for they easily catch the metal cuttings which work under the saddle, and form the chief factor in the wear of those parts. All things being considered, the author is of opinion that the requirements of paragraph (*a*) are more nearly met by a bed-plate with raised V's, the inner pair being set lower than has hitherto been the practice.

Release-nut Clutch.—The accuracy of the machine for screw-cutting will be effected by the construction of the clutch which operates the release-nut. There should be no possibility of side-flexure. Figs. 21, 22, and 23 show three ways of constructing this clutch.

With regard to paragraph (*b*).—It is one of the essentials in modern factories that a cutting-tool shall be made to work at as high a speed and with as heavy a cut as can mutually be worked together, which usually means frequent changes of speed to suit different diameters and variations in cut. The average workman is not, as a rule, particularly keen to get the utmost from his machine, and the greater the trouble to change the speed, the less often he will do it. It therefore follows that the more easily and quickly a change may be effected, the more likely is the machine to approach its maximum output. This points to the wisdom of making a machine handy, as per the requirements of paragraph (*b*). How, then, may these quick variations of speed referred to be obtained? Firstly, in the drive from the main to the counter-shaft, by using several sets of pulleys of differing diameters, or by friction cone-drives, or expanding pulleys; secondly, with ordinary stepped-cones in the drive to the lathe; and thirdly, with back-gearing.

Friction cone-drives have been put forward more of late. Messrs. Ward are making a facing lathe which has a chain connection from the cross-traverse screw to the striking-fork, so that as the screw is rotated to traverse the slide rest, a motion is transmitted to the striking fork by the chain. The relative motions are so arranged, that when the cutting tool is advanced towards the lathe centre, the striking fork is moved to give a greater speed to the lathe spindle, thus maintaining a constant cutting speed.

Back-gearing, as originally fitted, was of gear, necessitating the stoppage of the machine and the use of the spanner. The introduction of friction back-gearing is an improvement which greatly facilitates the change of speed, and is,

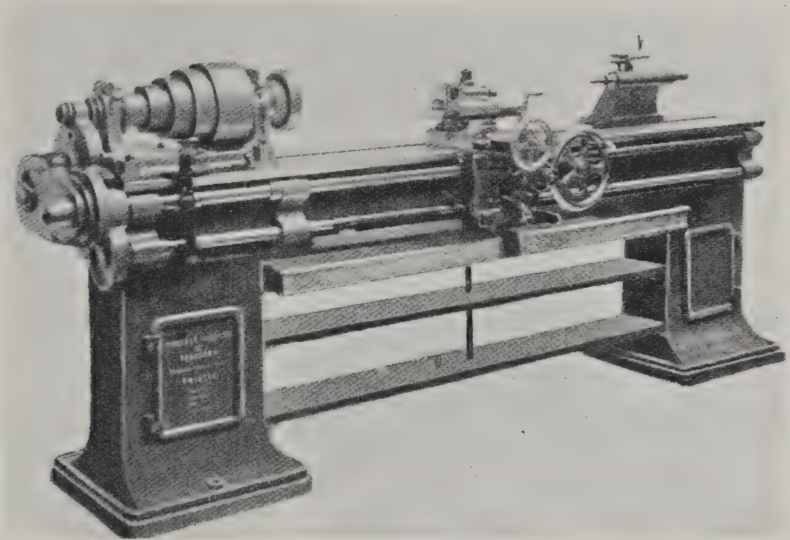


FIG. 26.—BRASS FINISHER'S LATHE (HUMPAGE, JACQUES, AND PEDERSEN).

undoubtedly, a valuable feature in the modern machine, which might with advantage be more generally introduced. A headstock with friction back-gear is illustrated in Fig. 28. With a headstock of this description, practically an instantaneous change over the back-gearing may be made, and, for this purpose, friction-clutches are introduced into the interior of the belt-cone and the large gear on the spindle. These friction-clutches are of the expanding brake-strap type, the expansion movement being produced by a simple form of toggle-joint A, Fig. 28.

Changes of Traverse.—A further requirement of paragraph (*b*), namely, that the changes of traverse should be effected by a handle movement practically instantaneous in action, is most important, both for ordinary turning and for screw-cutting.

An examination of the following methods now in use will be of interest. The change feed-motion largely adopted for the purpose of driving the traverse shaft

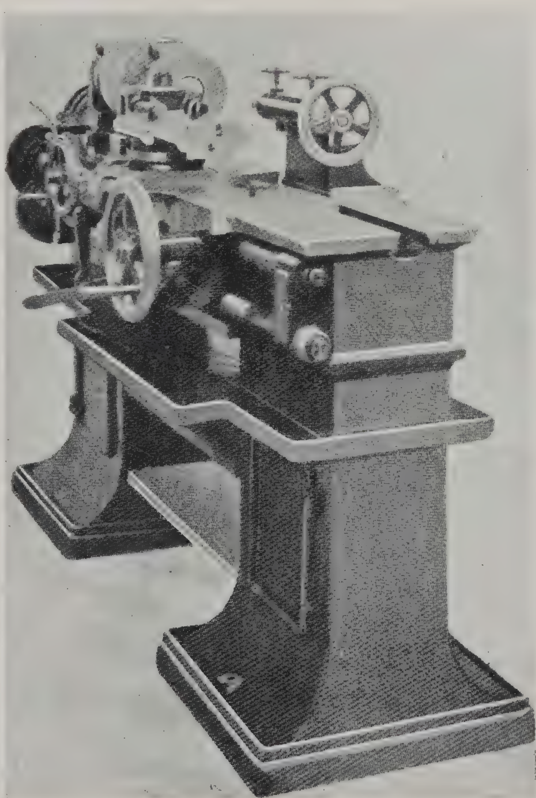


FIG. 27.—END VIEW OF ABOVE LATHE.

and lead-screws is shown in Fig. 29, it being part of an open-spindle capstan lathe.

A short driving spindle A is mounted the key K, its position determining which of the pairs of wheels shall be operative.

The centres of the shaft and spindle

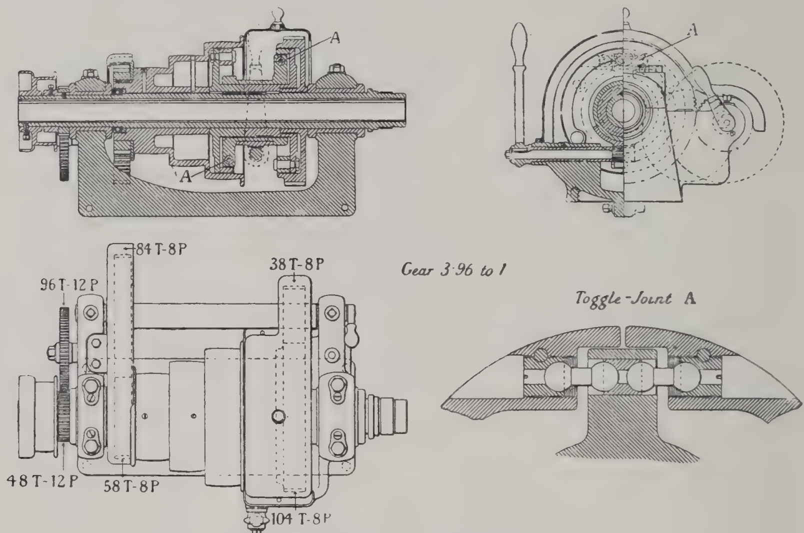


FIG. 28.—8-INCH HEADSTOCK WITH FRICTION BACK-GEAR (HERBERT).

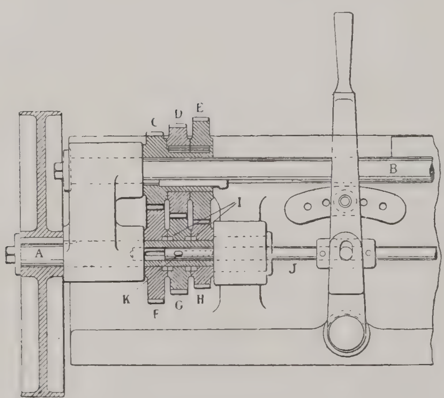


FIG. 29.—CHANGE FEED-MOTION (LANG).

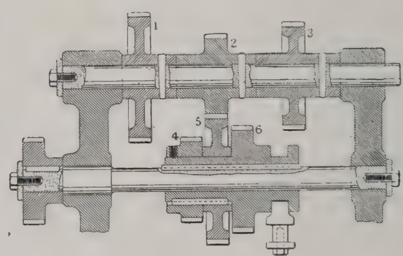


FIG. 30.—CHANGE FEED-MOTION (ARCHDALE).

parallel to the traverse shaft B, and three pairs of wheels, CF, DG, and EH, mesh together upon the shaft and spindle. The wheels upon the spindle each have six keyways, and they are also counterbored as shown in drawing at I. The spindle is bored and slotted to receive a rod J, armed with a cross-piece, which acts as a sliding key K. The handle, situated in front of the gantry, is used to slide the rod with

are $3\frac{21}{39}$ in. apart, and the wheels are paired as follows:—

First pair—

C $3\frac{1}{4}$ in. pitch diameter, 39 teeth.

F $4\frac{1}{16}$ in. ,, ,, 49 ,,

Second pair—

D 4 in. pitch diameter, 48 teeth.

G $3\frac{5}{16}$ in. ,, ,, 40 ,,

Third pair—

E $4\frac{1}{2}$ in. pitch diameter, 54 teeth.

H $2\frac{13}{16}$ in. ,, ,, 34 ,,

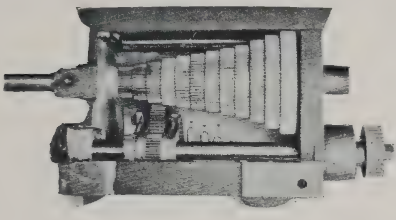


FIG. 31.—CHANGE-WHEEL FEED-GEAR (HENDEY-NORTON).

The pitch is 12 diametrical, and the feeds are $\frac{1}{32}$nd, $\frac{1}{24}$th, and $\frac{1}{16}$th respectively.

Messrs. John Hetherington & Sons use a similar mechanism, with four changes of speed, to drive their sliding and surfacing shaft in their 10 in. Sliding, Surfacing, and Screw-Cutting Lathe.

In the arrangement, Fig. 30, for a similar purpose there is also a driving spindle and traverse shaft. There are three pairs of wheels, but they are not continually in gear.

Those marked 1, 2, and 3 are each pinned to the traverse shaft. Upon the driving spindle there is a sleeve which is free to slide upon a feather key. Mounted upon it and forming part of the sleeve are three wheels—4, 5, and 6. The position of the sleeve can be regulated by a handle in front, which may cause either pairs of the wheels to mesh as follows:—

The first pair—
No. 1 has 55 teeth 10 pitch.
No. 4 ,, 35 ,, 10 ,,

Second pair—
No. 2 has 35 teeth 10 pitch.
No. 5 ,, 55 ,, 10 ,,

Third pair—
No. 3 has 45 teeth 10 pitch.
No. 6 ,, 45 ,, 10 ,,

The feed-change gear in Figs. 26, 27, 32, 33, is a modification of that shown in Fig. 29. The drive in this case is by roller chains, with three pairs of sprocket wheels. The driven wheels are mounted upon a sleeve which rides upon the end of the traverse-screw, and sliding keys are provided within the driven wheels.

The change-wheel system, as seen in Fig. 31, which is usually known by the name of the Hendey-Norton gear, is a very handy arrangement, and has been much copied. This gear serves to regulate the traverse for both screw-cutting, turning and facing. That it may apply for the several purposes, the lead-screw is cut with a keyway along its length, so that it serves both as a screw and a traverse-shaft. It will be interesting to learn the opinions of members on the use of the lead-screw in this dual capacity.

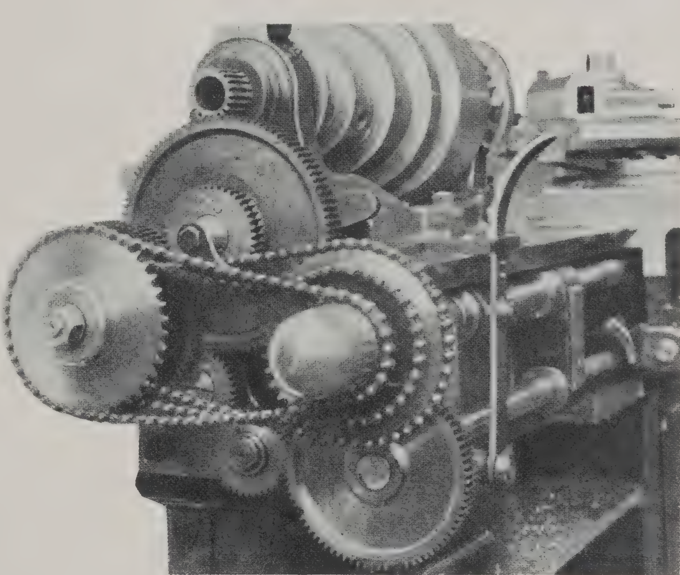


FIG. 32.—ROLLER CHAIN FEED-GEAR.

Change-wheels are used in the usual manner, the intermediate wheels being mounted upon a quadrant; but the number is very limited, as there are only two with 36 teeth, one with 140

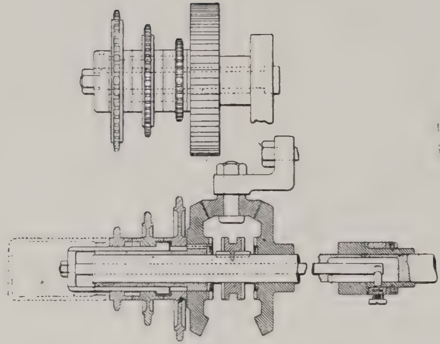


FIG. 33.—PLAN OF ROLLER-CHAIN FEED-GEAR SHOWN IN FIG. 32.

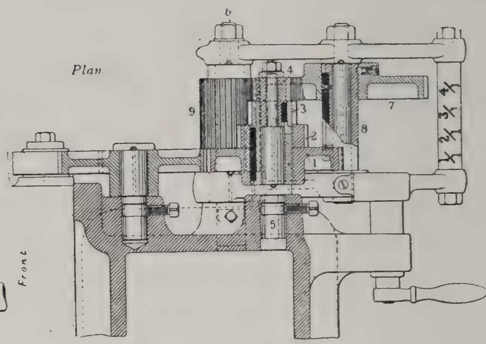


FIG. 34.—PLAN OF FEED CHANGE-GEAR (HERBERT).

and one with 69 teeth, though the latter, however, is used but rarely.

In front of the gantry is a gear-box through which the lead-screw passes, and, upon the portion within the box, there are twelve spur-wheels, the teeth ranging in order as in the Table 1. Directly beneath the screw is a short shaft, upon which, and within the gear-box, is mounted a sliding tumbler containing a pair of spur-wheels, the first upon the shaft and the second in gear with the first. This tumbler may be

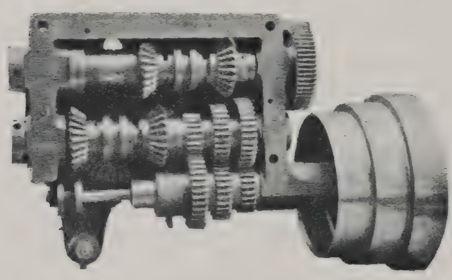


FIG. 35.—INTERIOR OF GEAR-BOX.

moved along the shaft until it is opposite either of the wheels upon the screw, and then raised to cause the second wheel to mesh with that upon the screw, where it is held in position by a spring catch. This action closes the train of wheels when the change-wheels have been set. In order that one of the change-wheels may be mounted upon it, the end of the short shaft projects beyond the gear-box, and thus the motion from the mandrel is transmitted by the change-wheels and the short shaft, and thence through the medium of the gears in the tumbler to the lead-screw.

In Table 1, the screw-threads which may be cut are placed in order below,

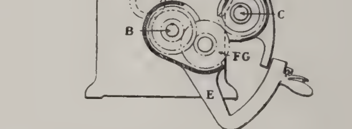


FIG. 36.—HEADSTOCK AND CHANGE-GEAR (LODGE AND SHIPLEY) END VIEW.

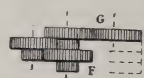


FIG. 37.—AUXILIARY CHANGE-GEARS.

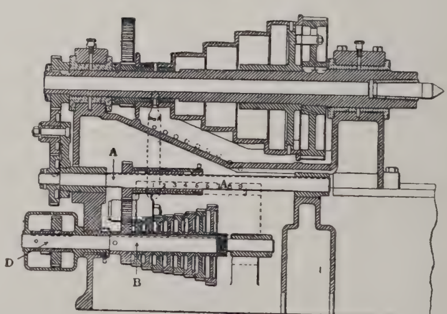


FIG. 38.—HEADSTOCK, SECTION SHOWING CHANGE-GEAR.

TABLE 1.

CHANGE-WHEELS AND SCREW-THREADS. (HENDEY-NORTON.)

Change-wheels.		Spur-wheeels in gear-box.											
on stud	on shaft	30	35	40	45	50	55	60	65	70	80	90	100
		Threads cut per inch.											
144	36	5	$4\frac{1}{2}$	4	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$
36	36	20	18	16	14	13	12	11	10	$9\frac{1}{4}$	8	7	6
36	144	80	72	64	56	52	48	44	40	36	32	28	24

When traversing with the reducing gear inside the apron in action, the number of cuts in the above Table are increased seven times.

The gears in the tumbler have 30 and 63 teeth.

the figure indicating the number of teeth in the wheels, and the change-wheels are arranged as indicated on the left. An inspection of the figures will show that all ordinary requirements are met when the two change-wheels with the 36 teeth are in use. Consequently, it is but rarely that, beyond the movements of the tumbler, a change of the wheels is necessary.

In the No. 2A hexagonal turret, Fig. 77, there are two feed-change gears; one is connected with the lead-screw, and the other with the traverse-shaft, each of which passes along the front of the lathe. The gear for the lead-screw has four changes, which are obtained in a simple way (Fig. 34).

Four spur-wheels, 1, 2, 3, 4, are fitted upon and form part of a sleeve which is free to rotate upon the fixed stud 5. Pivoted upon a second fixed stud 6 is a built-up swing-frame, carrying an intermediate wheel 7, the position of which may be varied upon the sleeve 8. Upon the fixed stud 6, and within the part embraced by the swing-frame, is a broad spur-wheel 9, which is driven, when in motion, by the intermediate wheel 7. The wheel 7 may thus move into either of four positions upon its carrying sleeve 8 and still mesh with wheel 9. By lifting the swing-frame, the wheel 7 may be caused to engage with either of the four wheels 1, 2, 3, 4, and the frame is then locked in position by a bolt in a quadrant forming part of the swing-frame. As the intermediate and driven wheels are used for each speed, the variation is entirely produced by the wheels 1, 2, 3, 4.

The teeth upon the wheels are as follows:—

Wheel No.	1	2	3	4
Teeth No.	72	36	24	18
Speed Ratios	1/1	2/1	3/1	4/1

By following the train of mechanism, it will be seen that the screw is finally driven through a train of bevel wheels placed within a gear-box at the front of the lathe-bed, Fig. 35. A small handle in front of the gear-box is available for setting over a double-claw clutch, thus stopping or reversing the motion. Within the gear-box referred to there is also a train of gears similar to Fig. 29, for regulating the speed of traverse, and in front of the box are handles for reversing and regulating the speed of traverse. The drive for this traverse is by belting to the gear-box from a three-speed cone on the tail end of the spindle, Fig. 35.

The feed gear applied by Messrs. Ward to their larger types of capstan lathes is a combination of that which is shown in Fig. 29, and that known as the Hendey-Norton. As already pointed

out, the former of these gears gave three feeds, and the latter twelve feeds for screw-cutting, and the same number for the automatic traverse. By a combination of the two gears, when one of them is applied to the drive for the first shaft and the other from the shaft to the lead-screw, they may integrate together, so giving a very wide range, and thus completely dispensing with the changing of wheels in the old way. The change applied by Ward are four pairs of meshed-gears with a sliding key on the spindle, and twelve gears upon the lead-screw, which give the following variations in traverse :—

two twin-gears F G, are free to rotate, which twin-gears are similar to each other, each consisting of two attached

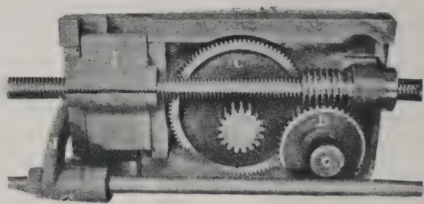


FIG. 39.—INTERIOR OF APRON, FITTED TO SLIDING AND SCREW-CUTTING LATHE (HENDEY-NORTON).

gears in the ratio of 1 to 2. When in position, the smallest spur-wheel at D meshes with the larger part of one of

TABLE 2.

SCREW-THREADS CUT BY CHANGE-GEAR. (WARD.)

A	4	5	6	7	8	9	10	11	12	13	14	15	per inch.
B	8	10	12	14	16	18	20	22	24	24	28	30	,, ,,
C	16	20	24	28	32	36	40	44	48	52	56	60	,, ,,
D	80	100	120	140	160	180	200	220	240	260	280	300	,, ,,

The letters indicate several pairs of gear which may be used to drive the parallel spindle.

Figs. 36, 37, and 38 show another modification of the Hendey-Norton gear, combined with a second change as in the Ward gear, but obtained in a different way.

It will be seen that below the headstock and within the bedplate there are two shafts, the upper one A the tumbler shaft, and the lower one B the change-gear shaft. Upon the portion of the lower one and within the bedplate, there is arranged a series of change-wheels, and, into either of these, the intermediate gears carried in the sliding tumbler may be caused to mesh as required. The second series of changes is in the wheel-train, between the gear-shaft B and the lead-screw C. The arrangement consists of a pair of gear-wheels keyed upon the shaft B at D, and their teeth are in the ratio of 1 to 2.

A quadrant E, pivoted about the shaft B, carries a spindle, and upon it,

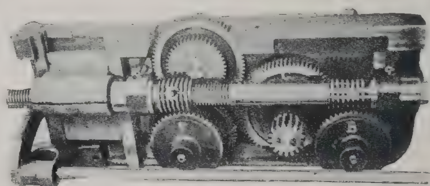


FIG. 40.—INTERIOR OF APRON, FITTED TO SLIDING, SURFACING, AND SCREW-CUTTING LATHE (HENDEY-NORTON).

the other twin-gears, and the largest spur-wheel at D meshes with the smaller part of the other twin gear, thus their relative speeds of rotation are as 1 to 4.

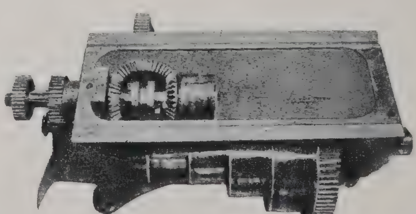
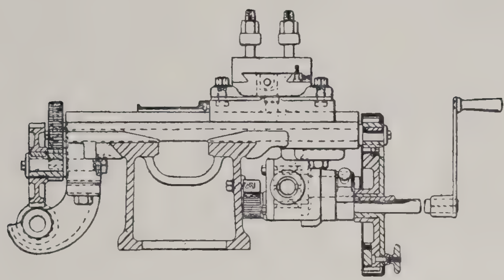


FIG. 41.—REVERSING GEAR FOR AUTOMATIC TRAVERSE (HENDEY-NORTON).



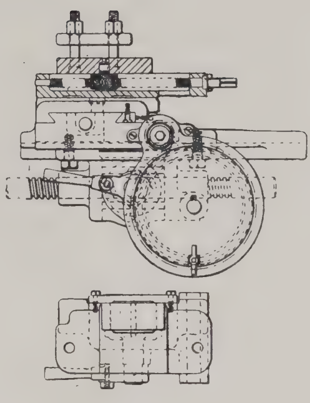


FIG. 42.—SADDLE AND SLIDE-REST (LANG).

The final closure of this train is a sliding wheel upon the end of the lead-screw, which, it is possible by a handle movement, to slide into either of four positions meshing with any of the wheels forming the two twin-gears, and the wheels are actually meshed by raising the quadrant. By this device, four different speeds may be given to the lead-screw for each position of the tumbler on shaft A.

The lead-screw on this lathe has a keyway along its length, so that it may act as a traverse-shaft, as in the Hendey-Norton lathe, the gear in the apron increasing the cuts per inch to the threads obtained from the screw in the ratio of 2·5 to 1.

Table 3 gives the threads and cuts with the combined gears.

Another requirement of paragraph (*b*) is, that the tool position should be readily changeable; therefore the question we have next to consider is, what movements of the tool are necessary, and how may they be obtained?

That the cutting-tool may be brought to an exact position, three directions of motion are essential.

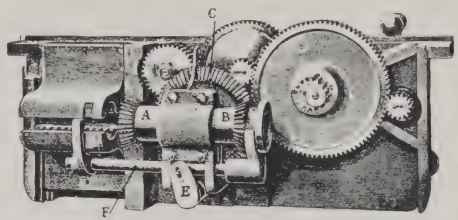


FIG. 43. INSIDE OF APRON (LODGE AND SHIPLEY).

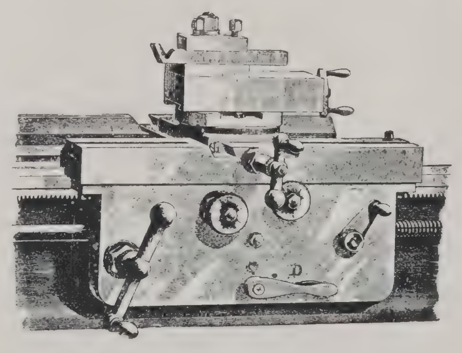


FIG. 44.—OUTSIDE OF APRON (LODGE AND SHIPLEY).

TABLE 3.

THREADS AND FEEDS. (LODGE AND SHIPLEY LATHE.)

Positions of sliding gear.	Tumbler positions.											Feeds.
	1	2	3	4	5	6	7	8	9	10	11	
A	—	18	19	20	22	23	24	26	28	30	32	30 to 40 per inch.
B	—	9	9½	10	11	11½	12	13	14	15	16	40 ,, 20 ,,
C	—	4½	4¾	5	5½	5¾	6	6½	7	7½	8	20 ,, 10 ,,
D	2	2¼	—	2½	2¾	2	3	3¼	3½	3¾	4	10 ,, 5 ,,

Firstly, in a horizontal plane in the direction of the lathe axis.

Secondly, in a horizontal plane at right angles to the lathe axis.

Thirdly, in a vertical direction.

As a rule, provision is made for ready adjustment in the first two directions by such means as the compound slide-rest; but for the third adjustment, we are rather too familiar with the use of metal packing strips varying in thickness. What is wanted is a quick vertical adjustment obtainable without loose pieces of any description, for which purpose several firms use elevating cross slideways, but in most of these arrangements stiffness and rigidity are sacrificed.

A further consideration of the movements of the tool in the horizontal plane, both parallel to and across the line of axis of the lathe, opens up a number of points for discussion, such as the relative merits of the ordinary English saddle with its compound slide-rest, and of the apron-saddle now being so largely fitted both in America and here.

As regards the English saddle, the longitudinal hand-traverse is effected by a rack-and-pinion motion without intermediate gear, and movement so obtained is very jerky and unsuitable for feeding the tool in its cut. Consequently, it is only used for shifting the saddle position when the tool is not in action, and the compound slide-rest is used for hand-feed or for fine adjustment of the tool.

As regards the apron saddle, the vertical front plate or apron has gearing within it for obtaining the various motions in an easy manner. For instance, there is gearing between the hand-wheel and the rack-and-pinion which gives enough mechanical advantage to enable the operator to give an easy and steady hand-traverse to the saddle with fine adjustments, thus rendering unnecessary the compound slide-rest.

These two types of saddles are illustrated in Figs. 39, 40, 41, 42, 43, and 44.

Fig. 45.

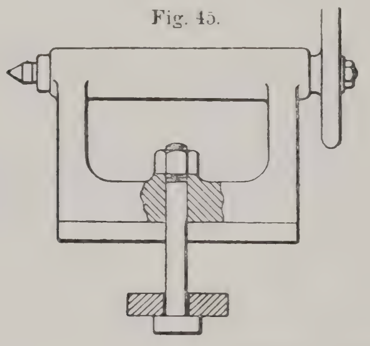
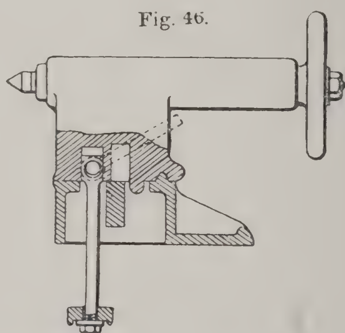


Fig. 46.



FIXING OF LOOSE HEADSTOCK.

English Saddle.—The saddle and slide-rest, Fig. 42, are fitted to an 8 in. sliding and screw-cutting lathe. The automatic traverse is obtained by worm-gearing from a shaft at the back of the machine. Passing through the saddle there is a light spindle which conveys the power to the gears at the front where there is a simple form of frictional connection to put the traverse into action. The release-nut, in two halves, actuated by a cam plate, slides in a small bracket beneath the saddle.

Apron Saddles.—Two photographs of the interiors of the aprons belonging to these saddles are reproduced, one as fitted to a sliding and screw-cutting lathe, Fig. 39, and the other a sliding,

surfacing, and screw-cutting lathe, Fig. 40. In each case it will be seen that the lead-screw being cut with a keyway acts in the additional capacity as a traverse-shaft, so that worms, carried by the apron, may slide upon the exterior of the screw-thread. These worms drive the gearing for both longitudinal and cross traverse. In Fig. 39 the worm A meshes with the worm-wheel B, which in turn drives wheel C and pinion D through a friction-cone, which is adjusted by a knurled nut in front of the apron. In Fig. 40 the same lettering applies to the traversing gear, but, in addition, there is a second worm E with gearing F, G, H for actuating the automatic surfacing feed. In both of these illustrations, I is the release-nut, the details of which are shown in Fig. 22. At the side of the apron is a handle J which slides upon the shaft K. A vertical movement of this handle either up or down causes a partial rotation of the shaft K, which, by levers and link, communicates with a bevel-gear train and double-claw clutch inside the headstock casting (see Fig. 41). Thus, from the saddle, the feed may be either checked or reversed—a very handy arrangement. There is also an automatic feed-knock-out, which is not shown in the illustrations. As already stated, the automatic feed is put into action by a friction-cone actuated by a knurled nut in front of the apron. It is the assumption that this friction-gear will make it impossible for antagonistic feeds to be in action at one time; but in practice this is not so, for the fact is, that, as the worm and worm-wheel are constantly in gear, the rotation of the spindle upon which the worm-wheel is mounted, tends to automatically tighten the nut and cause the cone to seize. If it does so while screw-cutting, as the worm-gear gives a different rate of traverse to the screw, something must break. The author has had the rack of a Hendey-Norton lathe broken three times in this way, purely by accident. The design of this apron may thus be seen to meet the requirements of paragraph (*g*), but it fails as far as paragraphs (*e*) and (*h*) are concerned.

To meet the requirements of (*h*) a neat interlocking mechanism, shown in Figs. 43 and 44, here effectually prevents the possibility of two speeds of traverse entering into action at one time. The feed traverse is in this case also derived from the lead-screw acting as a shaft; but, instead of a worm, a sliding sleeve with two bevel-wheels, A and B, is mounted within the apron.

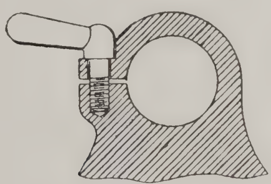


Fig. 47

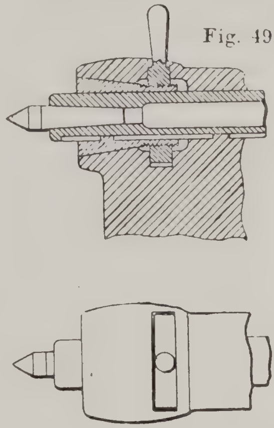


Fig. 49.

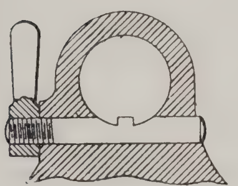


Fig. 48.

BACK-CENTRE LOCKS.

These bevels may be meshed with a third one C, from which both the longitudinal and the cross-traverse wheel-trains are driven. The handle D (Fig. 44) operates the lever E, which, in turn, slides the bolt F. On one end of this bolt a claw is mounted which determines the position of the sleeve with the bevel-wheels, and at the other is a lock for the release-nut. Thus it will be seen that unless the bevels are both out of gear, it is impossible for the nut to close upon the lead-screw, by which arrangement the requirements of (*h*) are fulfilled, and by a slight further alteration (*e*) would be also fully satisfied.

The abolition of the compound-rest necessitates other modifications in the machine, such as cutting away the saddle to clear both the fast and loose headstocks, that the tool may get home to the centres. Further, as the fiddle-slide of the compound-rest is not available to set to an angle for turning tapers, other means must be provided if such work is to be done.

The apron type of saddle has been modified to specially suit the turret-saddle and cross-slide of the larger types of turret lathes, where automatic traverse is essential. Good examples of such aprons may be seen in Figs. 73 and 74.

On many machines the *loose headstock* is constructed in two parts, and provision is made to set over the top portion to throw the centre out of line and so obtain the taper required. In the author's opinion such a method as this is bad, as, in a machine where accuracy is essential, such accuracy being dependent upon the setting of centres and slides, disturbance should not be permitted when it has once been tested and proved accurate. The only remaining methods of obtaining the taper are, then, either to provide a means of compounding the longitudinal and cross-traverses by gearing in any desired ratio, or to use an adjustable former. The first of these two methods is used in a few designs, but it is too complicated, so the latter seems to be the better solution of this problem.

As to the final requirement of (*b*).—Of the methods of fixing illustrated in Figs. 45 and 46, the former, although most largely used, requires the objectionable loose spanner, whereas the latter, operated by a handle and eccentric movement, may be considered more satisfactory.

Figs. 47, 48, and 49, show three methods of locking the centre slide, and of these the last tends, when locking, to keep the slide in position, whereas the others are likely to spring it out of place.

(To be continued.)

PUMPS: THEIR CONSTRUCTION AND MANAGEMENT.

By PHILIP R. BJÖRLING,

Author of "Pumps and Pump Motors." *

(*Concluded from page* 146.)

DOUBLE-ACTING PULSATING STEAM PUMPS (*continued*).

THE "Niagara Falls" pulsating steam pump is illustrated in perspective Fig. 85, sectional elevation Fig. 86, and sectional end view Fig. 87. The principal difference in this pump from all other pumps of this class is the valve. The inlet is, as usual, at the top, and the steam immediately enters the chamber, in which there is a vibrating angular valve. The central diaphragm is continued into the steam space, which is divided by it. The two steam ports are formed in angular faces, on the apex of which a Λ shaped valve is suspended, so that it rocks on this point. The result is, that the centre of gravity of the valve is below the point on which it is pivoted, thus aiding in its free movement and taking away much of the objection which prevails to this type of pump. The area of the steam ports is very large, so that a very small movement of the valve is followed by a free inlet of steam. When the steam has filled one chamber the valve, owing to the vacuum pulling it down, closes the inlet to the chamber, opening that of the other. This pump is manufactured by Messrs. W. T. Ellison & Co., Limited, of Manchester.

* E. & F. N. Spon, Ltd. £3 3s.

SINGLE-ACTING PULSATING STEAM PUMPS.

This class of pulsating steam pump is not so numerous as the double-acting one.

The "Criton" steam pump, manufactured by the Pulsometer Engineering Company, is illustrated in Fig. 88. It has been designed for situations where a cheaper form of apparatus than the pulsometer is desired. The steam valve gives more favourable results as regards steam economy than that of any other pump of this description. They are fitted with special valves—balls, for example—when very thick or even fibrous liquids and semi-liquids have to be pumped. They will work on lifts of 100 ft. or more with suitable steam pressure; with 50 lb. steam pressure at the pump, it will raise water to a total height of 80 ft. They are made with steam inlet pipes, varying from ½ in. to 2 in. diameter, delivering from 2,000 to 40,000 gallons of water per hour.

The last pulsating steam pump we will draw our readers' attention to is the one illustrated in sectional elevation, Fig. 89. The peculiarity in the construction consists in that there is no steam valve for distributing the steam.

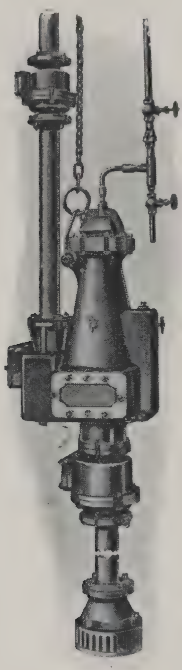


FIG. 85.—"NIAGARA FALLS" PULSATING STEAM PUMP, MADE BY MESSRS W. T ELLISON & CO., LIMITED., MANCHESTER.

A is the working or condensing chamber; C the suction branch, and E the suction valve; F is the delivery valve, and D the delivery pipe, forming a dip pipe in the delivery valve-box; G is a pipe connecting the working chamber A with the delivery valve-box, and L a pipe connecting the working chamber with the air vessel B; R is the air valve; K the steam inlet pipe; J the throat; H is the valve-box cover for access to the delivery valve.

The action of this pump is as follows: The steam flowing in through the steam pipe depresses the water in the working chamber A, driving it through the delivery valve F, and up the delivery pipe D. This is done without disturbing the level of the water, consequently the top layer of water in immediate contact with the steam becomes heated, and, by reason of its reduced density, remains at the top, thus preventing further conduction. A portion of the water passes into the air vessel B, through the small pipe L, where it remains under a pressure equal to that of the working chamber A. In this manner the water level falls until it arrives at the offset, when a violent disturbance takes place, and a reduction of pressure is, in consequence, brought about. The injection water now rushes in from the air vessel B, and completes the vacuum, causing a fresh supply of water to enter from the suction pipe. The inrush of the suction water is so violent that it is necessary to restrict the passage way into the working chamber A, and to take in a small

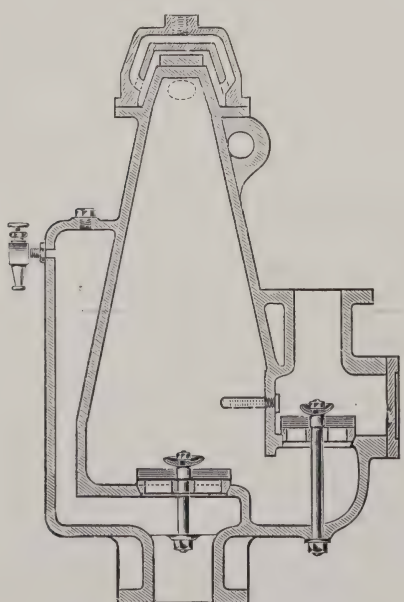


FIG. 86—SECTIONAL ELEVATION OF "NIAGARA FALLS" PUMP.

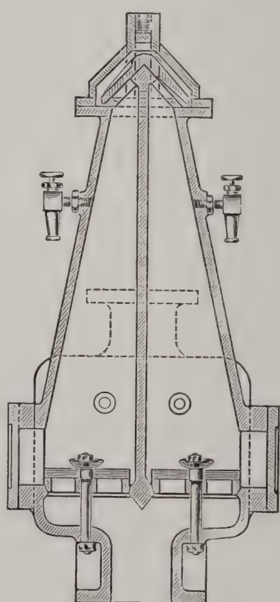


FIG. 87.—SECTIONAL END VIEW OF SAME.

amount of air through the snifting valve R. This air serves the double purpose of cushioning the flow of water, and subsequently, by mingling with the steam, preventing condensation of the latter by reason of its low conductivity. The working chamber A being now filled again, the action is repeated so long as the steam valve remains open and there is water to pump. The flow of steam is practically constant, as the vacuum period is extremely short; therefore, very little condensation of steam takes place. From this, it will clearly be seen that this pump requires no steam-controlling valve whatever beyond the ordinary steam-stop valve.

It may be set to work either by priming the pump and suction pipe with water through a plug hole provided for the purpose on the side of the working chamber A, or in the following manner: Assuming that the suction pipe is empty of water, the steam is turned on and rushes into the pump, expelling the air. After the air has been expelled the steam is shut off, and allowed to remain off a few seconds whilst condensation takes place, creating a vacuum in the working chamber, and causing the water to flow up the suction pipe. This operation is repeated two or three times, when the pump will be found to be filled with water, and the steam may be left on after the attendant has regulated the amount to be admitted to attain the best results.

FIXING AND MANAGEMENT OF PUMPS.

In choosing the class of pump and valves the utmost care must be exercised, and it is best to leave it to an expert or experienced maker, for everything depends upon the class of liquid, fluid, or semi-fluid which has to be dealt with; as, for instance, if we have to pump anything thick, we must not use a plunger pump, we must have a piston; if we pump tar we must not have any brass or gun-metal near the tar; if we pump sugar solution, treacle, or salt or saline water, we must not have any cast-iron in the pump, it must be all gun-metal. If we have to pump any thick fluid the piston valve is the best; if paper pulp, a can valve acts better than any other class of valve we are

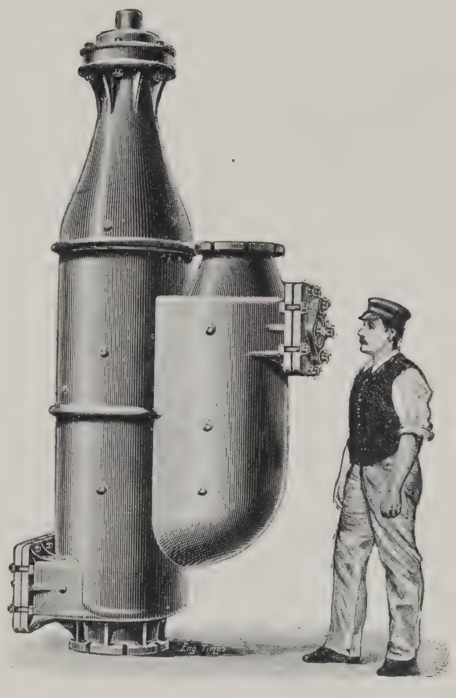


FIG. 88.—VIEW OF THE "CRITON" STEAM PUMP MADE BY THE PULSOMETER ENGINEERING CO., LIMITED.

acquainted with, but they must be made of lead or antimony, or an alloy of the two, or some other metal which will resist strong acids. For extra strong acids a mixture containing as much antimony as possible, consistent with the valves being soft enough to machine and bed to their becting faces. Clack valves should be avoided, because they are sluggish in their action. The hinge side does not move, therefore the amount of lift which is given to perpendicular lift valves must be given to the clack

in the centre of the water way; hence, the side furthest away from the hinge must travel twice the distance; however, for paint and semi-liquids they may be used with advantage, because there cannot be so much "slip" or liquid returning into the suction pipe with thick as with thin liquids. We cannot go any further into these interesting details, because we have already overstepped the space allotted to us for these articles, and we have yet to make a few remarks about fixing and the management of pumps.

When fixing a new pump of any description great care should be taken that all sand, grit, dirt, iron or brass cuttings, etc., are carefully cleared out of the working barrel, because frequently great damage has been done to pumps, pistons, plungers, pump rods, and glands by being cut by it.

In connecting up the pipes to a pump, great care should be taken to adopt the size of pipe specified by the maker, and that any packing rings used are provided with a hole so much larger than the diameter that, when the joint is screwed up, the joint ring does not reduce the bore of the pipe.

All bends should be easy, having, where possible, a radius not less than three times the diameter of the pipe.

It is always the best plan, where practicable, to provide a dirt-box or strainer, as near the pump as possible, and when the suction pipe is long a suction air vessel, sometimes termed a vacuum vessel, should be provided on the suction pipe near to the suction branch of the pump.

A good arrangement of pipes, air-vessels, dirt-box or strainer-box, and stop-valves, as adopted by the Worthington Pumping Engine Company, is illustrated in Fig. 90.

On the suction pipe A is provided a foot-valve B, which keeps the pipes and working barrel charged with water, so that the pump, when being started, does not have to free itself and the suction pipe from air. This valve is always necessary on long suction pipes, and great height of suction. C is the suction air vessel, on the top of a T-pipe, bolted to the suction pipe. D is the dirt-box or strainer-box, one flange of the box being attached to the suction branch of the pump, and the other to the suction pipe. A basket strainer is inserted from the top of the box through the cover, through which the water passes, and which basket can easily be withdrawn, for cleansing, through the cover.

A back-pressure valve, E, is placed upon the delivery pipe to keep the water back when the pump is examined or undergoing repairs. A small pipe, F, is placed below the air vessel, so that, when the valve on it is opened, the pump can start and free itself from air, while the pressure is kept from it by the back-pressure valve E. When the pump has properly started, the valve F should be closed. G is a charging pipe connecting the delivery pipe, outside the back-pressure valve, with the suction pipe or suction chamber of the pump, for the purpose of charging the working barrel and suction pipe, before starting, with water or other liquid, from the rising main, in case the pump has been purposely emptied or the water having leaked out through the foot-valve.

A pressure or delivery air vessel should be placed on the highest part of the pump, so that all the air entering with the water will find its way into it. The generality of air vessels supplied with pumps are a great deal too small, so that they are worse than useless, in fact, they are more detrimental than of any use. Air vessels for large pumps should be fitted with some kind of apparatus, so as to keep a constant supply of air in it, suitable to the class

of pump or pumps and the pressure the pump is working against. The best apparatus of this description we know of is Wippermann and Lewis's air charger, manufactured by Messrs. Frank Pearn and Company, Limited, West Gorton, Manchester.

This apparatus is illustrated in Fig. 91, which shows a sectional elevation of a horizontal pump fitted with this air charger. A is a cylinder or small supplementary air vessel, its piston being the liquid from the main pump; at the bottom of this vessel is a pipe B, fitted with an adjustable cock or valve C, attached to the main pump valve-box, immediately below the delivery valve. At the top of the air vessel A is a small gun-metal valve-box D, fitted with inlet and outlet valves; from the latter a delivery pipe E communicates directly with the main air-vessel G, on the main pump; F is a glass water gauge fitted to the small air vessel A, so that the level of the water can be seen.

The action of this apparatus is as follows: When the main pump draws the liquid the air vessel A will be partially emptied, the amount being regulated by the cock C. When the return stroke takes place the whole of the air drawn into the chamber A through the suction valve in the valve-box D is delivered into the main air vessel G, through the pipe E, because the pressure in the main pump, when delivering, is in all cases greater than the pressure on the suction side.

The distance between the main air vessel G and the small supplementary air vessel A can, of course, be any length. If they are separated the apparatus is placed either on a pillar or on the wall of the pump-house in any convenient place.

All joints should be kept perfectly tight, especially those on the suction side, both for to obtain the best duty of the pump as well as to keep the outside clean and free from rust.

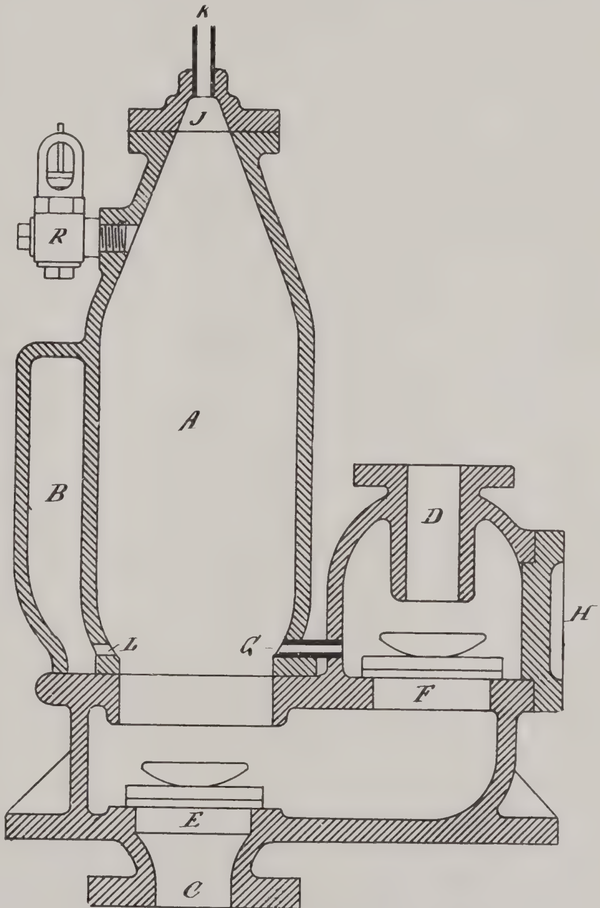


FIG. 89.—SECTIONAL ELEVATION OF PULSATING STEAM PUMP, WHICH HAS NO STEAM VALVE FOR DISTRIBUTING THE STEAM.

When starting a pump, it sometimes happens that it is not able to move the column of water, on account of the full pressure of the column resting upon the delivery valve, because the air in the body of the pump is not driven out, but only slightly compressed; therefore, it is

always best to run the pump empty a few strokes, so as to clear the pump of air. This cannot, of course, be done in all cases; therefore, it is best to have a connection between the rising main or delivery pipe and the working barrel, or suction chamber, as has already been explained and illustrated in Fig. 90. The wheel valve is opened so as to form a communication between them; the water from the rising main enters and equalises the pressures and forces the air through the delivery valve into the rising main, or air vessel, if the pump is properly designed, so as to allow the air to escape, instead of lodging in it; a simple and good plan is to have a small pet cock placed directly under the delivery valve, for the air to escape through.

If, after taking the above precautions, there is any difficulty in starting a pump properly, when new, it will generally be found to proceed from imperfect connections, or from the temporary stiffness generally found in any new machinery.

All the stuffing boxes should be carefully packed and the glands evenly tightened up. The best packing for the plunger, in plunger pumps, is hemp and tallow; the hemp must be carefully and evenly plaited and steeped in warm melted tallow, Russian tallow being the best.

In pit work, great care must be taken that the plunger and bucket pumps are quite linable with the rods, or there will be more thrust on one side than on the other, hence the gland for the plunger will wear oblong; or if the plunger is softer than the gland, the plunger will wear more on one side than on the other; and the bucket leathering, in bucket pumps, will wear out faster on one side than the other.

When the pump is worked by a beam, T-bob, L-box, or angle-bob, the centre line of the pump must be taken by bisecting the *verse sine* of the arc formed by the travel of the beam, etc., from the top to the bottom of the stroke, or the wear will be more on one side than the other.

The pump rods should always be well lubricated and kept clean; grit and dirt should not be allowed to accumulate on the lubricant, because it causes the rod to be flucted. Lubrication of the plungers greatly retards the corrosion when the water is acidulated. If the water is heavily acidulated, it is best to have the plunger either made of solid "Delta metal" or phosphor bronze, or cast-iron covered with either of those two metals; the covering is rather doubtful when working against heavy pressures, as the liquid might, and frequently does, find its way between the cast-iron and the "Delta metal" or phosphor bronze covering.

Piston pumps should be allowed to run a day or two, then the pistons should be taken out and examined, to see that the packing is good and properly bedded, if metallic packing is adopted. After that the piston should be taken out periodically, and examined. The pump attendant, or pitman for large pumps, as the case may be, will soon know from experience how long the packing or leathering will last; it varies, as we have previously mentioned in these articles, with the quality of the water pumped. At some collieries the leathering only lasts a day, at others many months.

The pump valve faces and the valve beats on the seats should also frequently be examined, to see that they are good, so that no slip or back-flow of the liquid into the suction pipe takes place, down the valve seat.

There is one peculiarity with some india-rubber discs, used for valves, which we believe is very little known, but deserves to be carefully noticed, that is, that if one of the faces of the disc is placed towards the grid seat the disc

becomes slightly convex on the bottom face and a great amount of water slips back into the suction pipe, but if the disc is turned round it becomes all right for work. We have carefully examined both sides, but totally failed to see the slightest difference in the appearance or texture. We have inquired of india-rubber manufacturers the reason why this is sometimes the case, but cannot get a, to us, satisfactory answer. This fault is magnified when the centre of the disc is nipped tight between the guard and the grid seat.

When there is a hammering or knocking in the pump when it is at work it is a proof of faulty, leaky joints in the suction pipe, the pipe being too small for the size of the pump, or the suction valves out of order, so that the working barrel does not become perfectly full of liquid pumped at each stroke, the hammering being caused by the piston or the flat end of the plunger, as the case may be, meeting the liquid.

The thicker the liquid, fluid, or semi-fluid raised is, the less height of suction can be resorted to, and for hot liquids it is best if possible to let it run into the pump.

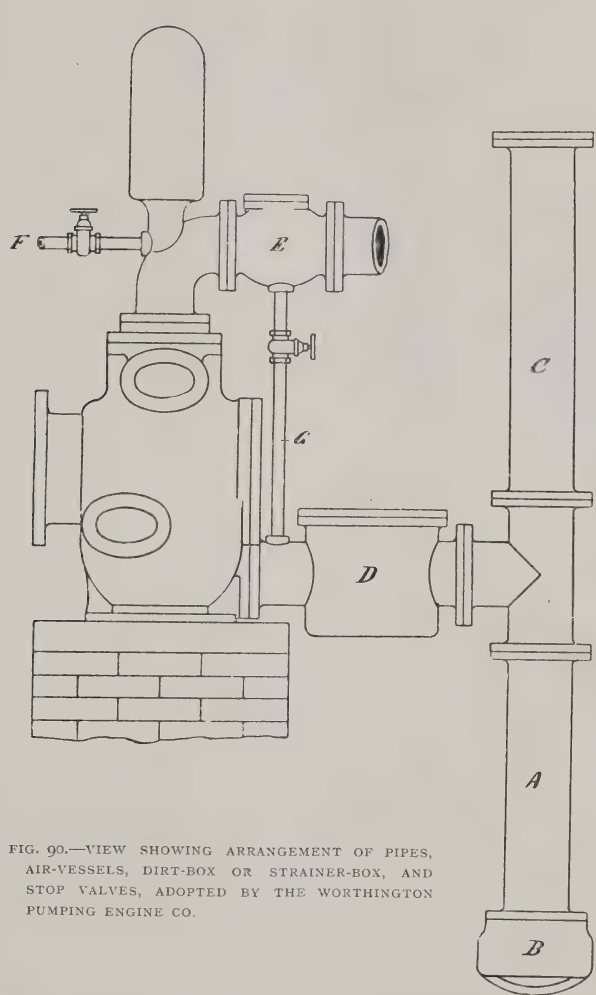


FIG. 90.—VIEW SHOWING ARRANGEMENT OF PIPES, AIR-VESSELS, DIRT-BOX OR STRAINER-BOX, AND STOP VALVES, ADOPTED BY THE WORTHINGTON PUMPING ENGINE CO.

All pumps that are exposed to cold weather should be provided with drain cocks, and when the pump is stopped all the liquid should be run out of it, to prevent it from freezing.

Horizontal pumps of the plunger type should be provided with a sludge cock under the lowest part of the working barrel, so that any accumulation of sand, grit, or sludge can be blown out at intervals.

We have frequently gone to examine pumps, which would not work satisfactorily, that were so completely covered with dirt that it was impossible to see where the joints in the covers and pipes were before the thick coating of filth was scraped off with a chisel, and the engine in the next room clean, bright, and polished, almost fine enough for a drawing-room. We have asked how it was, and the reply received has been: "Oh! it is only a pump." Why should the pump, which in most cases is quite, if not more important than the engine, not receive the same attention? Surely

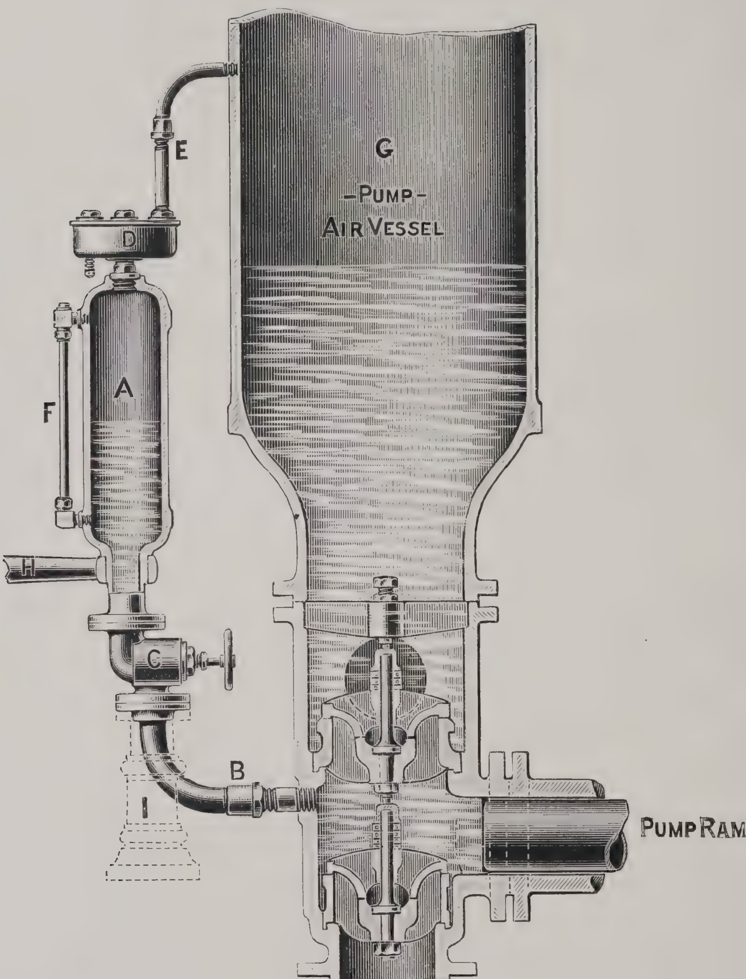


FIG. 91.—SECTIONAL ELEVATION OF HORIZONTAL PUMP, FITTED WITH MESSRS. WIPPERMANN AND LEWIS'S AIR CHARGER.

a well-attended pump will last longer, work better, cause less trouble, and be less liable to get out of order. Our advice is to keep it clean, nicely painted a clean-looking, pleasing plain colour, and keep it in good order; it will then be a pleasure to the attendant, instead of, as is frequently the case, a constant source of anxiety and trouble. When you are looking after the interest of your pump you are looking after your own interest.

Philip R. Björling

THE PRODUCTION AND USE OF ACETYLENE GAS.

By W. DOMAN.

INTRODUCTORY.

IN the series of articles commencing in this number the intention is to develop the pract cal rather than the theoretical part of the subject, and to place the reader in a position to make choice of the most satisfactory method of producing and using acetylene, and to enable him to design and erect the necessary plant for this purpose.

Although, at the present time, the most up-to-date apparatus leaves but little to be desired in the way of simplicity and effectiveness, it is hardly likely that our present methods are incapable of radical changes; but they undoubtedly show sufficient evidence of permanency to deserve the close attention both of the practical man and the student.

The advantages and uses of acetylene lighting, regulations as to storage and carriage of carbide, and a short description of its manufacture are included, to make the general usefulness of these papers as complete as possible.

The chemistry of acetylene has been but lightly touched upon, and the student is referred for fuller information to Prof. Lewes' work, to which I am mainly indebted for the figures and facts relating to this part of the subject.

For the greater portion of the chapter on carbide I am indebted to Mr. Chas. Bingham, who has very kindly placed at my disposal a paper written by him on this subject, which I here give *in extenso.*

I.—CARBIDE OF CALCIUM.

Up to the present time the honour of having discovered calcium carbide (carbide of calcium or calcic carbide, as it is often called) has been attributed to the German chemist Wöhler, the French chemist Moissan, and the Canadian engineer Willson.

Wöhler prepared carbide as early as 1862, but his process produced only an impure compound; and as he made no use of electricity, his discovery has proved of little value for present-day practice.

Moissan, however, may fairly claim to be the father of the calcium carbide industry, at any rate in Europe. His descriptions of the process to be employed to produce carbide in the electric furnace, which he first began to publish in 1892, and his beautifully complete investigations of its properties, still form the most exhaustive original work we possess on the subject.

To the Canadian Willson, also, a meed of praise must be awarded. While endeavouring to prepare metallic calcium in the electric furnace, in 1892, he accidentally obtained calcium carbide. With the shrewdness characteristic of his continent, he saw that a substance which could apparently be so easily prepared, and yielded an illuminating gas by simple contact with water, should have a brilliant commercial future before it; and with great tenacity he continued his experiments, with a

view to production on a commercial scale. It was, however, not until some months after Moissan communicated his celebrated 1894 paper to the world, through the *Comptes Rendus*, that Willson filed his 1894 patents, which constitute his strongest claim to be one of the first discoverers of commercial carbide.

Investigations carried out by the writer some months back, in connection with a patent case, show, however, in the clearest way, that the honour of first discovery does not rest with either Wöhler, Moissan, or Willson, but with an American scientist, Dr. Robert Hare, of Philadelphia.

Dr. Hare, who appears to have been taking the cruder electrical appliances at his disposal into consideration, as indefatigable an investigator as Moissan, read in 1839 and 1840 several papers, which are published in *The American Journal of Science*, on the production of "carburet" (as "carbide" was then called) of calcium, and described a method of making it, by subjecting a mixture of quicklime and carbonaceous matter, placed on the bottom electrode of an electric furnace, and immediately below the upper electrode, to the heat produced by passing the current from 200 large Cruikshank cells through it; or, in other words, by subjecting the mixture to the heat of the electric arc.

Dr. Hare describes the product obtained, and states in his communications that it oxydized in the air, and that when brought into contact with water it gave off an "odorous" gas. He did not, however, realize the value of the product he had discovered, nor would he have been able to make much use of it, even had he known its value, as the cheap current of the dynamo was not at that time available.

In May, 1895, the Acetylene Illuminating Company put up a small plant at Leeds, with steam power for making carbide commercially; the Electro Chemical works at Bitterfeld starting in February, 1895, thus about the same time, on the Continent.

From that moment the industry began to develop with gigantic strides, too fast indeed, for in 1900 many of the weaker works had to shut down, owing to over-production.

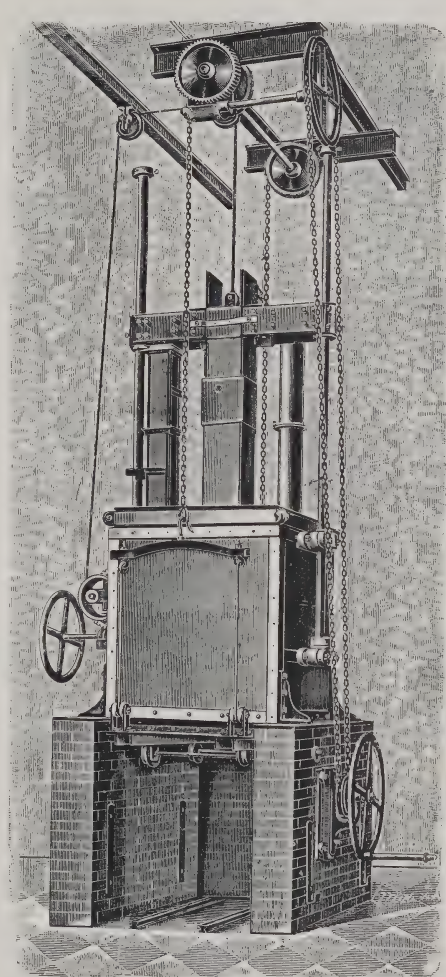


FIG. I.—VIEW OF ELECTRIC FURNACE, MADE BY MESSRS. KELLER AND LELEUX.

Carbide of calcium consists simply of 62·5 per cent. by weight of calcium, and 37·5 per cent. of carbon, and is formed by fusing together, in the electric

furnace, a mixture of lime and coke, charcoal, or anthracite coal. Its specific gravity is 2·22. Theoretically, it should yield, on being brought into contact with water in proper proportions, 5·9 cubic feet of acetylene at a temperature of 60° F. Owing, however, to various causes, the yield is rarely more than 4·8 cubic feet per lb. of carbide. In appearance, it much resembles some kinds of limestone; but varies in colour from almost black to a lightish purple. It is almost as insensible as stone to fire, or anything except water, brought into contact with which it will produce a volume of acetylene equal roughly to 400 times the space occupied by the carbide when broken ready for use.

Carbide is sent out by the factories broken to almost as many sizes as there are factories. The sizes most used in the United Kingdom are 6 in., 4 in., 2½ in., 1 in., ¾ in., and ⅛ in. mesh. The 2½ in., owing to the dimensions of trays or cells generally used, is the size most suitable for the majority of generators; the ¾ in. is the best size for cycle lamps.

Although experience is growing, many generator makers, and still more private users, do not yet realize the importance of obtaining carbide of a proper size for the kind of generator they sell or use. Small pieces should not be used for generators working on the "drip system," or where the water rises to, or falls upon, the carbide in small quantities; nor should very large lumps be used where the carbide is allowed to fall into an excess of water.

No high-class carbide works now send out carbide that has not been properly screened, but many carbides, even of good quality, are so soft, owing to the method of manufacture, that attrition during transport will cause a considerable quantity of dust, the bane of all generators. As a rule, carbide made on the "tapping" system, *i.e.*, carbide drawn off in the molten condition through a tap-hole in the furnace, bears transport better than any other; as it is harder and more compact. It is a singular fact that even when a "tapping" furnace is used, all parts of the same charge will not yield the same amount of gas per lb., so that the only way to obtain an approximately equal yield per drum is to break up an entire charge, carefully sample the various parts, and fill each drum with pieces from various parts.

We give here an illustration of one of the most successful electric furnaces for the manufacture of carbide of calcium. The first is that designed by the German Gold and Silver Refinery, of Francfort, which has been supplied to a great number of works in Europe.

The mixture of lime and coke, or coal, is not broken into dust, but into pieces about the size of a nut, and fed into the furnace.

The products of combustion, which rapidly eat away the electrodes, are led away at the side of the furnace, and the cost for electrodes thereby greatly reduced. This furnace is a so-called "ingot" furnace, *i.e.*, the carbide is not "tapped" off, but is allowed to remain in the furnace and cool, when it is removed in the solid state. It gives a remarkably high yield per unit of electric energy employed, the guarantee being 5 kilos (say 11 lbs.) of 4·8 ft. carbide per kilowatt-day. In actual practice this figure is usually exceeded.

The German Gold and Silver Refinery, having undertaken the sale for the Mid-European Carbide Combine, is now paying less attention to the manufacture of the furnaces.

The next furnace we illustrate shows another system, *i.e.*, the "tapping" one

referred to above. This method of making carbide is gradually displacing the "ingot" system, owing to the carbide produced by it being more regular in quality, and more homogeneous.

In the "ingot" furnaces only the centre part, or "core," consists of good quality carbide; the outer part is "crust" or "shell," giving too little gas to be sent out, and as it is, as a rule, extremely difficult to distinguish where "core" ends and "shell" begins, and workmen cannot always be depended on, "ingot" carbide often proves to be a source of much trouble to the maker. "Tapped" carbide can, on the other hand, be always relied upon to give satisfaction if good materials be used and reasonable care be exercised.

The "tapping" furnace we illustrate is that made by the Keller and Leleux Co., of Paris, which many of our readers probably saw at the late International Exhibition. The drawing shows how the molten carbide is drawn off from the furnace. To get over the difficulty of the tapping-hole clogging, a difficulty which causes much anxiety in carbide works, Messrs. Keller and Leleux allow the hole to gradually close up, and a cake of carbide to form in the furnace. The power is then transferred to a second furnace, and the first one allowed to cool down, when the carbide remaining in the tapping-hole and furnace can easily be removed. Lately this firm have devised an improved furnace, to a great extent obviating the difficulty of the tapping-hole choking up.

This furnace is one of the best of its type, and in actual working gives approximately the same results per kilowatt of energy as the ingot furnace of the Francfort firm. The Francfort furnace has been the most extensively used by works adopting the "ingot" process, while the same may be said of the Keller and Leleux furnace for the "tapping" process.

Another system is that known as the "incandescent." In furnaces of

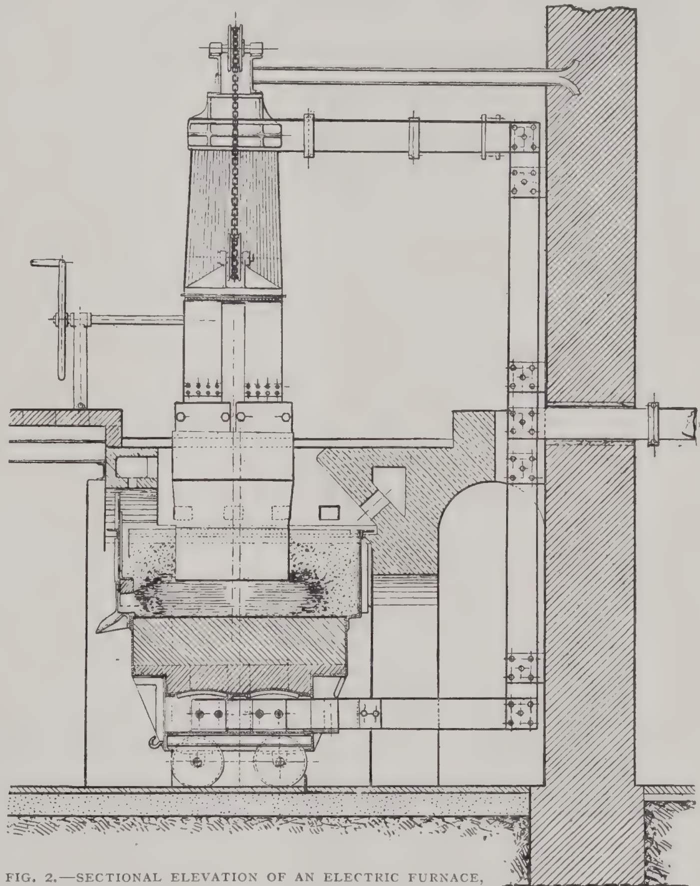


FIG. 2.—SECTIONAL ELEVATION OF AN ELECTRIC FURNACE, MADE BY MESSRS. KELLER AND LELEUX.

this description the electric arc is not used, the resistance of a poor conductor, such as a carbon rod, broken pieces of carbon, etc., being employed to produce the electro-thermic effect required.

In spite of the fact that the two Cowles, the fathers of the electro-metallurgical production of aluminium, used incandescent furnaces, and these have also been successfully employed for other purposes, such as the production of carborundum, a successful carbide furnace on this principle was not devised until the Giffre Electro-Chemical Co. were able last year to get over the difficulty of making the incandescent furnace a "tapping" furnace, and thus obtaining carbide of equal homogeneous quality. The Giffre furnace has been steadily improved, and the yield is so good, both as regards quantity and quality, that the designers anticipate obtaining in the near future much better results than shown by any arc furnace. The consumption of electrodes, a very sore point with carbide makers, is extremely low with this furnace.

In the meantime, the above-mentioned firm (Keller and Leleux) also succeeded in designing a most ingenious tapping furnace working on the incandescence principle. Space, unfortunately, prevents a full description being given, but we may mention that the furnace consists practically of a crucible with two vertical electrodes arranged in it side by side, one being movable in two directions, viz., vertically and horizontally, in such manner that at the moment of tapping, it is close to the side of the crucible where the tapping hole is situated, and thus keeps the carbide near the tapping-hole in a perfectly molten condition.

With care in the manufacture, a high-grade carbide can be made from any good metallurgical coke, charcoal, and most of the anthracite coals from the South-west Wales anthracite field. This latter district is now supplying the bulk of the carbon requirements of the European carbide works.

The good metallurgical cokes contain, as a rule, very little phosphorus, while the Welsh anthracites, usually used for carbide making, often show either the merest traces, or practically none at all. All, on the other hand, contain a fair proportion of iron and sulphur, originating, as a rule, from iron pyrites. Nearly all the sulphur is evaporated off in the electric furnace; most of the iron remains, and part of it forms the bright white metallic specks visible in most carbides. The bulk, however, is, as a rule, melted down into a solid lump of silicide of iron, when it can usually be detected and picked out. Occasionally it escapes attention, and is found by the generator user in the residue. Really good lime, on the other hand, is not easy to obtain. The greatest enemy in the way of impurities is magnesia, which appears to coat the lime and carbon with an extremely fine film, preventing, to a great extent, proper chemical union, so that a charge of what appears to be perfectly fused carbide will sometimes yield so little gas that it cannot be sent out.

The next worst enemy is phosphorus, found in many limes in the shape of phosphate of lime. It is to this impurity that is due what is known as acetylene "haze," *i.e.*, a vapour-like cloud, which, in the case of very bad carbides, used without proper purification of the gas, can be so dense that it is difficult, as the writer once saw, to distinguish the performers on the platform across a large concert room.

Silica is generally held to be very prejudicial, but the writer believes that a much higher percentage of this oxide can be tolerated in the raw materials than is generally believed to be the case. One of the best carbides made in the South of France is prepared from

anthracite small coal, "duff," which has been shown by regular analysis of each consignment to contain, on an average, 10 to 11 per cent. of ash, fully one-half of which is stated to be silica.

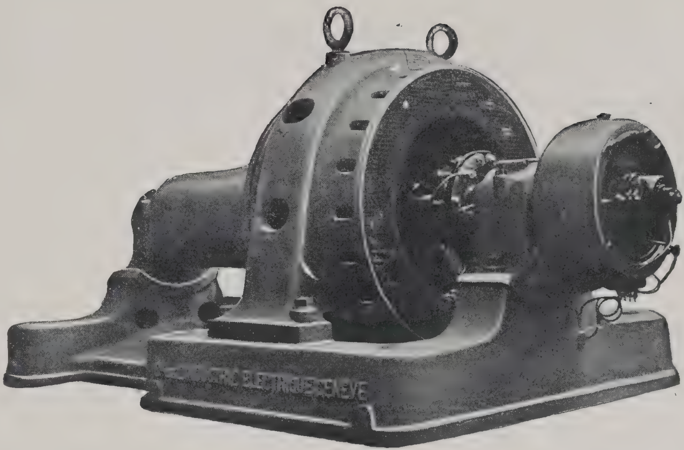


FIG. 3.—SPECIALLY DESIGNED ALTERNATOR, BY ELECTRIC INDUSTRY CO., GENEVA.

Although anthracite is now employed to so great an extent, metallurgical coke is generally preferred by carbide makers, where it can be obtained at approximately equal prices, the carbide produced from coke being of slightly better quality.

Gas coke is generally thought to be unsuitable for carbide making, but it is worth mentioning that the extensive carbide works at Deutsch-Matrei, Tyrol, have been using it.

It is often stated by laboratory carbide experts that a greater proportion of lime is required to make "tapped" carbide than to make "ingot." Such is, in the writer's experience, not the case. On the contrary, both the works which claim to hold the record for low consumption of lime per ton of carbide made, use the tapping process. It would also appear from the figures which have been published from time to time—and especially from the paper warfare that took place in Germany between Birgson and Frœhlich in 1900—that "tapped" carbide can be produced at least as economically, even as regards the quantity of current used, as "ingot" carbide of an equally high standard of quality, say 4·8 cubic feet per lb. Nor have any facts of practical value been adduced to show that the statement made by Lewes, probably on the information he received from Germany, to the effect that a higher temperature is required in the furnace to tap the carbide, is correct.

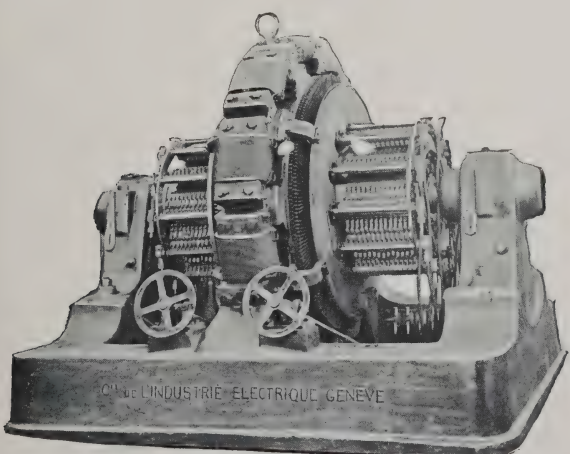


FIG. 4.—SPECIALLY DESIGNED CONTINUOUS CURRENT DYNAMO.

Dr. Frœhlich, who has probably had more experience than Prof. Lewes, says the exact contrary is the case.

The heat required to fuse lime and carbon together in order to make carbide is generally given at 3,000° C. This figure is probably exaggerated. The writer has assisted at commercial runs when a higher yield of c.c. has been obtained per unit of current used than the theoretical maximum yield amounts to, basing on above temperature, and allowing for

the difference between the quality of the commercial carbide produced and theoretically pure carbide. The Alby carbide works claim to produce more carbide per h.-p. year than the theoretical yield basing on a temperature of 3,000° C.

At the present time, a first-rate furnace will produce about 13 lbs. of c. carbide of 84 per cent. purity per kilowatt-day of 24 hours (the current measured at the furnace connections), equal to about 1·2 ton per h.-p., and year of 300 days. Owing to breakdowns, occasional failure of charges, etc., one ton of 84 per cent. carbide per h.-p. year is at present looked upon as a fairly good output.

COST OF PRODUCTION.

Many of the laboratory experts put the cost of making carbide at £2 10*s*. to £3 10*s*. per ton above the cost of the power; thus, with power at £2 per ton, the total cost would be £4 10*s*. to £5 10*s*. per ton. Adding, say, £2 per ton for costs for management, this makes the cost, exclusive of power, £4 10*s*. to £5 10*s*.

The fallacy of this calculation is clearly shown by the fact that when the price of carbide dropped, towards the end of 1900, to £12 per ton at the factory, including drums, the cost of which can be taken at £2 5*s*. per ton, half the carbide factories in Europe had to shut down. One of these, which had been working at full power, paid only 30*s*. per electric h.-p. year of 7,200 hours, the power being measured by a meter installed in the works, at a few yards' distance from the furnaces.

The writer has had the opportunity of comparing figures with many prominent makers, and the general opinion seems to be that, without allowing for any profit, and with power at £2 per electric h.-p., and year of 7,200 hours, a price of about £8 to £9 should be the cost of production, when working on a large scale. To this price must be added the manufacturer's profit and the cost of drums, so that the statement of the German experts that £13 to £14 is a fair selling price at the works, including drums, seems not unreasonable. Without doubt, however, this price will go down: on the one hand, owing to constant improvements in the manuture; and on the other, owing to the recent great drop in the price of the carbon—coke or coal—used.

STORAGE OF CARBIDE.

The Board of Trade being of opinion that the stone-like solid carbide "presents dangers similar to those presented" by the fluid petroleum, has placed the former, with a few alterations and additions, under the provisions of the Petroleum Act of 1871.

Five pounds of carbide may be stored without a licence, provided that it is kept in hermetically sealed metal receptacles, holding not more than 1 lb. each. The ordinary, self-closing 1 lb. tins are usually held to comply with these conditions. On the Continent, as a rule, 10 kilos (22 lb.) may be stored in one vessel without a licence, and the limit will probably soon be raised in the United Kingdom.

Where more than 5 lbs. are stored, a licence, costing 5*s*., must be obtained from the "local authorities."

These are:—

(*a*) In any harbour: the Harbour Authority.

(*b*) In the City of London: the Corporation.

(*c*) In Greater London: the London County Council.

(*d*) In any borough: the Town Council.

(*e*) In any place in Ireland within the jurisdiction of any Trustees or Improvement Commissioners: the said Trustees or Commissioners.

(*f*) In any place in Scotland within the jurisdiction of Police Commissioners or Trustees exercising the function of Police Commissioners: the said Commissioners or Trustees.

(*g*) In places where there is no local authority as defined above:

(1) In England and Wales: the District Council.

(2) In Ireland: the Justices in Petty Sessions.

(3) In Scotland: the County Justices. The licences are for one year, and renewal must be applied for if desired.

Little difficulty is usually encountered in obtaining licences. For quantities up to 1 cwt. a dry cellar, room, or shed is usually passed. Above 1 cwt., the carbide must usually be stored in a shed or outhouse not connected with the building (although a shed built on the flat roof of a house has been passed).

All vessels containing carbide must be labelled:

"CARBIDE OF CALCIUM.

"DANGEROUS IF NOT KEPT DRY.

"The contents of this package are liable, if brought into contact with moisture, to give off a highly inflammable gas."

They must also bear the name and address of the owner (in the case of a vessel kept); or the sender (in the case of a vessel sent or conveyed); or of the vendor (in the case of a vessel sold or exposed for sale).

The maximum weight allowed to be packed in each drum varies, but is usually 1 to $1\frac{1}{4}$ cwt.

CARRIAGE OF CARBIDE.

The British railways require the carbide to be packed in substantial, hermetically sealed iron drums, or, if in tins, the latter must be packed in iron drums, or stout cases, iron bound. Each package must be labelled in the same manner as the vessels, and a special consignment note must be used.

As carbide is, in many cases, only carried on "explosives" days, great delays are often experienced, especially when the consignment has to pass over two or three systems.

British shipowners have steadfastly set their faces against carrying carbide, although it is an undoubted fact that it is infinitely safer than a vast number of other articles carried. Unwillingness to investigate a new branch has practically driven this large and increasing trade into the hands of foreign lines; the export of carbide from British ports is at present impracticable.

ELECTRIC PLANT.

As a rule, the current used for carbide making is alternating monophase, although in some instance triphase is employed, notably in the case of the works at San Marcello, North Italy.

Preference has been given, in the majority of cases, to the alternating type, owing to its ability to withstand the very exacting requirements of carbide manufacture.

Herein are shown, in Figs. 3 and 4, two dynamos especially designed for electrothermic purposes by the Electric Industry Co., of Geneva, who have supplied the greater part of the dynamos employed for this work in Europe.

While it is undoubtedly a fact that for the manufacture of calcium carbide alternating current is to be preferred to a continuous current, the writer would certainly not, at the present moment, advise its adoption, as without costly rotary transformers it is difficult to utilize the current for any other purpose if, as at the present moment, the output of carbide exceeds the demand. If direct current be used, the prime cost of the plant is somewhat increased, but the current becomes available for making alkalies, extracting and depositing

copper, and various other electro-lytic, as well as electro-thermic, purposes.

This very complete paper of Mr. Bingham's leaves hardly anything to be said on the subject of any service to either the generator maker or user, except, perhaps, to emphasize the fact that carbide varies both in quality and in its action in the generator, and that to obtain the best results this point should have more attention paid to it than has been the case hitherto.

For a machine of the "drip" or "*slow* contact" type the largest lumps procurable are the best, and yet, up to the present, there has been the greatest difficulty in making certain of supplies of the 4 to 6 in. sizes, which are required by at least two of the foremost generators on the market, and would be used by many others if proper attention were given this point by the makers of the apparatus. This is not the fault of the carbide makers so much as that of the users.

It is rather a pity that the "ingot" carbide, formerly made at Foyers, should be now almost unprocurable. The large lumps or "H" size of this make could not be beaten for "drip" or "slow contact" machines, probably owing as much to the shape of the lumps as to the make. The large pieces of the "tapped" carbide have very irregular surfaces, and are more or less of a flat shape, while those of the "ingot" make were larger, of straighter surface, and more nearly of a square shape. Irregularity of surface would doubtless increase the tendency to intense local action, and a flat underside obstruct the free escape of gas.

The ideal form of carbide for this type of apparatus would doubtless be that of comparatively thin plates or rods standing upright, and separated from each other by a space equal to that occupied by the excess in bulk of the moist lime produced by the action. It is practically impossible to satisfactorily generate acetylene from a mass of comparatively small lumps of carbide.

The question of quality is practically one of economy only. A poor make of carbide is not necessarily impure in the sense of containing objectionable products, and may be caused by an excess of either lime or carbon, by incomplete combination in the furnace, or by a mixture of "crust" with the good. Such carbide, if sold at an equivalent price, is as good for most generators as one giving the full yield of gas; and even a carbide containing an excessive amount of sulphur and phosphorus can be utilized to produce pure gas at a slightly increased cost for purifying material.

(To be continued.)

W. Doman

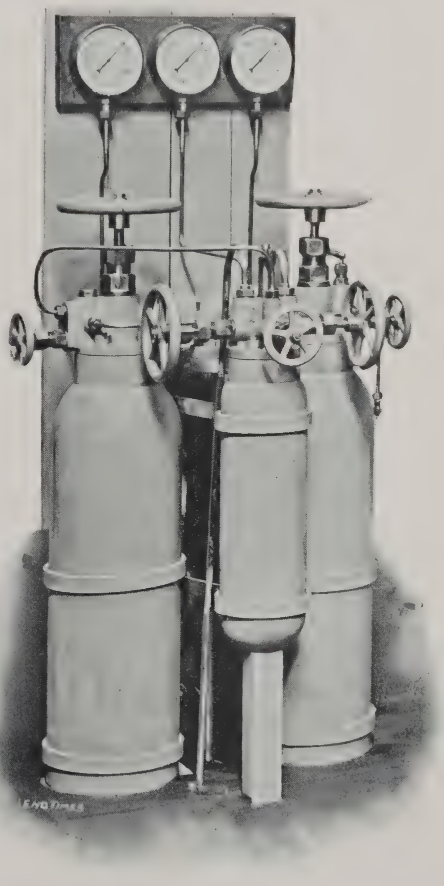
NEW MACHINERY, APPLIANCES, ETC.

(Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated so far as possible by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.)

THE "DIESEL" OIL ENGINE.

THE demonstration of the working of the "Diesel" Oil Engine, which took place at the works of Messrs. Scott and Hodgson, of Guide Bridge, Manchester, last week, must be regarded as an event of more than ordinary importance, for not only is this the first "Diesel" engine made in this country, but also the first one of its kind ever constructed on the two-stroke system. In other countries "Diesel" engines have been built on the four-cycle or "Otto" system, but in this instance practically double the power is obtained with the same size cylinder. There is no doubt that the "Diesel" engine, from a scientific standpoint, is a distinct advance on ordinary practice in oil engine construction.

It is doubtful whether the economic working of an "Otto" engine can be improved to any appreciable extent by still further increasing the compression before ignition, because the charge is liable to explode in a hot cylinder before the completion of the compression stroke. Instead of drawing in a mixture of air and oil vapour and then compressing it, the "Diesel" engine compresses the air by itself to over 500 lb. per square inch, thus raising the temperature to somewhere near 1,000° F., and then into such compressed air is sprayed the required amount of oil, when combustion takes place, producing the desired mechanical effect: therein lies the principal novelty of the "Diesel" engine. There is con-



APPARATUS FOR STARTING THE "DIESEL" OIL ENGINE.

siderably more air let into the cylinder than is necessary for the complete combustion of the oil, the object being to keep the temperature within reasonable limits. How complete the combustion was, was demonstrated at Guide Bridge by placing a sheet of white paper over the exhaust, and keeping it there for a considerable time without its becoming soiled.

In the two-cycle horizontal engine illustrated in our frontispiece, the combustion takes place every alternate stroke of the piston, which equals one power stroke to each revolution. The engine has a cylinder diameter of $7\frac{7}{8}$ in., a stroke of $10\frac{3}{4}$ in., and gives 19 b.h.-p. at 210 revolutions per minute. When we saw the engine at work, it ran very smoothly, and without excessive noise. It was at the time driving a line of shafting and developing about 15 h.-p. The illustration would show it to be somewhat complicated; but this is more apparent than real, and we believe there is nothing in this connection to retard its progress, and on the two-stroke system there does not appear to be any practical reasons why the "Diesel" oil engine should not be made for comparatively large powers.

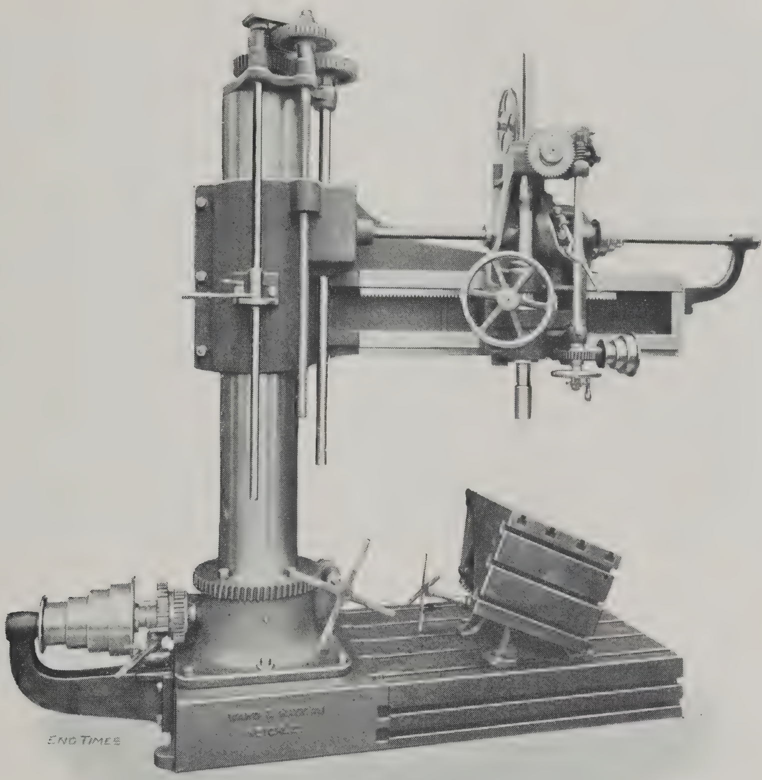
We also reproduce a photograph of the apparatus for starting the engine, which we have seen working very satisfactorily; in fact, on the occasion to which we refer, the engine was started in something under eight seconds. This device works in this way: The engine is fitted with a small pump, which stores air in the two largest cylinders at about 600 lb. pressure per square inch. This is sufficient to run the engine for a few revolutions independently of the oil feed, which is for the moment out of action. When the engine is fairly running, and can compress its own air in the cylinder to over 500 lb. to fire the charge, the oil inlet valve is thrown into action, and the usual cycle of operations are performed, and the starting cylinders automatically recharged to their original pressure.

What of oil consumption? On this point, in regard to the Manchester engine, there is, as yet, no data available, but we hope to be able to give some in an early issue. As to what has been done on the Continent and America, however, we can inform our readers. The Augsburg Manufacturing Company guarantee that "Diesel" engines of any size made by them will work with ·452 lb. of solar oil or of crude petroleum per b.h.-p. hour, and at half power the consumption will not exceed ·520 lb. Lord Kelvin says, "Diesel has actually obtained 58 per cent. more work than any that had been given, from the same weight of oil, by any of the best oil motors previously made." From a report by Prof. Unwin, we learn that "it works with about five-eighths as much oil as the petroleum engines hitherto constructed." Prof. E. Meyer, in a report informs us that when using raw Tegernsee oil, of a specific gravity of ·789 at 68° F., an engine he tested consumed ·467 lb. at normal load, ·488 lb. at three-quarters load, and ·567 lb. at half-load. Somewhat similar results have been obtained by such experts as Professors Schörter, Zeuner, Hartmann, and Denton, who all affirm that this engine consumes about 50 per cent. less oil than any other engine.

The company owning the patent rights of the "Diesel" engine in this country is the Diesel Engine Company, of 171, Queen Victoria Street, E.C., and we shall follow with considerable interest the lines on which they will proceed to develop this remarkable engine. The general opinion seems to be that its greatest scope lies in the direction of powers over 100 horse, but we think this is a matter which can only be determined by actual experience in building.

RADIAL DRILLING MACHINE.

We illustrate an up-to-date Radial Drilling Machine by Messrs. Ward and Haggis, Keighley. This machine has been specially designed with a view to handiness in work. It consists of a strong table or bed with T slots on the top, and down the front side. On the arm slides the drill head is adjustable by rack and pinion and hand wheel. It is fitted with steel spindle working in large cast iron socket with conical bearings, provided with check nuts to take up the wear. It has self-acting and hand-feed motions by means of the three-speed cone and rack and pinion, is provided with ball bearings to take the pressure of the cut, and is balanced by means of weight sliding down a rod at the back of the drill carriage. It is also provided with quick down setting and withdrawing motion, the self-acting gear being disengaged by means of excentric socket, which, at the same time that it disengages the self-acting feed, brings into gear two spur wheels, which gear direct into the rack pinion shaft, by means of which one revolution of the hand wheel on feed shaft raises or lowers the spindle four inches, thereby dispensing with any unsightly levers, etc., as well as making the tool very handy. The spindle can be stopped, started, and reversed, by means of the clutch on drill head without interfering with the overhead motion. This clutch when thrown out also disengages the feed motion (which is not the case



RADIAL DRILLING MACHINE, BY WARD AND HAGGIS, KEIGHLEY.

with many machines) thereby preventing breakages of drills, etc. The arm can be turned through a complete circle by means of a worm and worm wheel, and is raised and lowered by power by means of reversing gear at the top of the pillar and screw, the handle for operating same being within easy reach of the attendant.

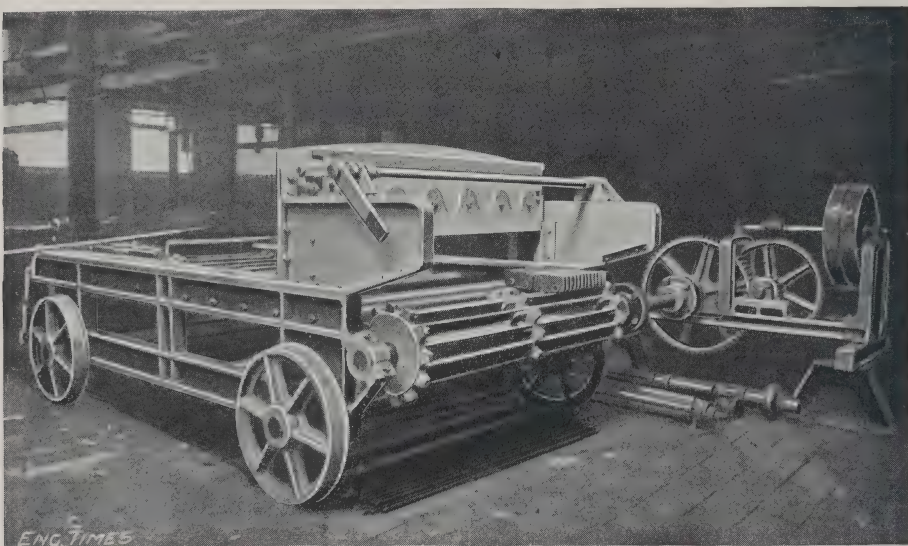


FIG. I.—SHOWING THE MOVABLE GRATE AND MECHANISM OF THE "JUCKES" FURNACE.

THE "JUCKES" FURNACE.

THERE is quite a remarkable number and variety of mechanical stokers and fire grates in use at the present time, each maker endeavouring to construct their apparatus automatic as far as possible. Some of these work exceedingly well for a time, but in the majority of cases something eventually goes wrong with the gear, or the grate burns out, and the user is glad to return to the use of the common grate with plain fire bars and hand firing. However, there are a few that are fairly satisfactory, and amongst these none is constructed upon better principles than the old "Juckes" furnace. Great improvements have been made upon this type lately, and a good number are at work, and giving every satisfaction both for steam raising and boiling in breweries. It must be clearly understood that the "Juckes" furnace has always been designed for consuming small coal or slack, and is generally worked without blowers or steam jets. Fig. 1 shows one of these as erected in the fitting shop of Messrs. Richard Moreland & Son, Limited, London, who are one of the earliest makers, and whose improvements in the last few years have added considerably to the value of the furnace. Fig. 2 shows a similar furnace to Fig. 1 as fitted under brewery coppers. It will be observed that the fire grate is in the form of an endless chain (in this case six feet wide) which passes over a drum at each end, the front drum being the driving one. The grate can be regulated in speed from fifteen to twenty-five feet per hour to suit the quality of fuel, or thickness of feed to grate. A hopper in front of the fire door is kept filled with fuel, and the door, which is the same width as the fire

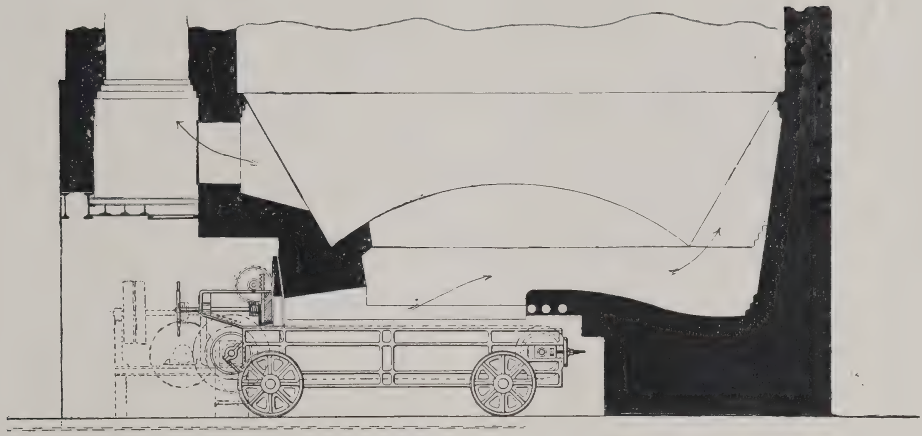


FIG. 2.—"JUCKES" FURNACE AS FITTED TO BREWERY COPPERS.

grate, can be regulated by hand to give whatever thickness of feed desired, and the fire grate continually moving drags the fuel under the bottom edge of door. Any clinker formed on the grate is carried under the bridge at the back end. This is first cooled by water tubes, and finally broken up when turning over the back drum into the ash pit. As already stated, both the feed door and the fire grate can be regulated so as to insure perfect combustion. The writer has seen three of these furnaces connected to one chimney with no smoke being emitted. Fig. 4 shows a "Juckes" furnace as fitted to a Lancashire boiler for steam raising, and Fig. 3 as a dust destructor. This type of furnace is regarded by many engineers as an ideal one for dealing with towns' refuse, and the writer believes that it will come more into favour. At present the main

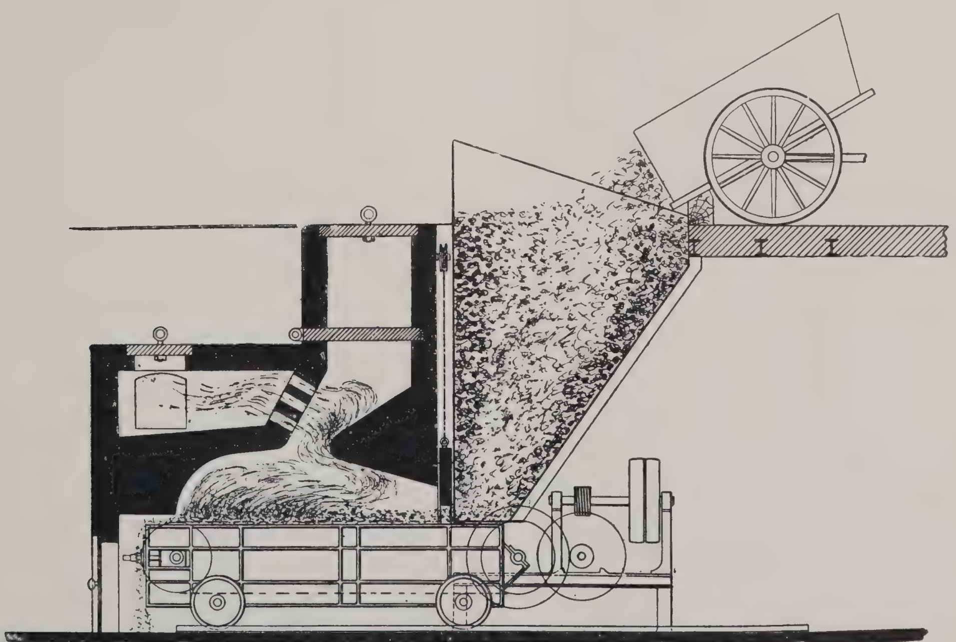


FIG 3—THE "JUCKES" FURNACE FITTED AS A REFUSE DESTRUCTOR.

objection is its first cost, but considering

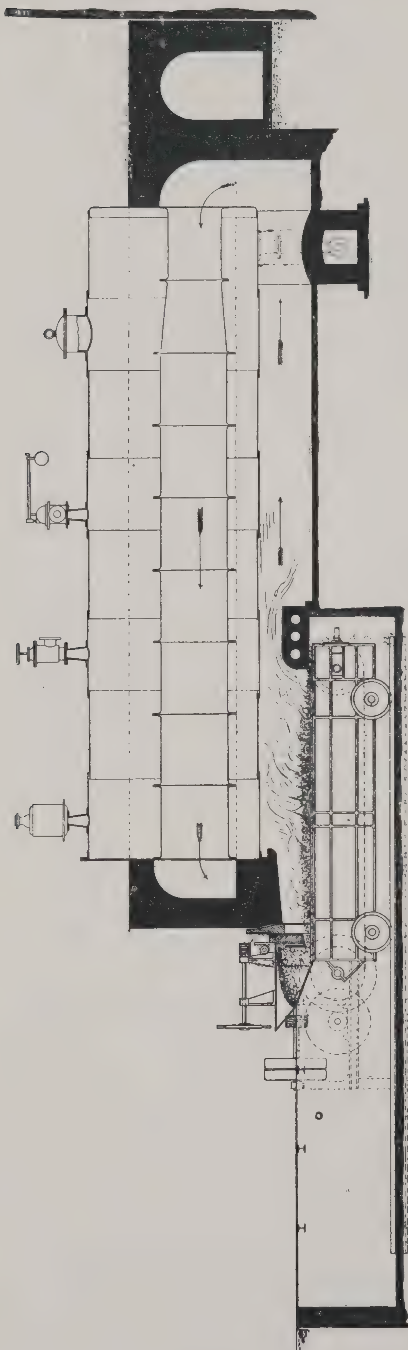


FIG. 4.—SHOWING "JUCKES" FURNACE FITTED TO A LANCASHIRE BOILER

that it will work without stoppage for repairs for from three to five years, this alone should be sufficient to warrant its use in this connection. A cremator is shown fitted in Fig. 3 for dealing with infected bedding, etc. It will be observed from the illustrations that the "Juckes" furnace can be run out clear of the boiler or destructor, a point which minimises trouble in case of necessity for repairs or examination.

WILLIAM S. KERR.

ENGINEERING NOTES.

Sewage Disposal.

We have been requested to state that the Atcham authorities, through their surveyor, Mr. J. Morris, have been making inquiry into the various methods of sewage disposal, with a view to the adoption of a scheme; and after visiting a number of sewage purification works, Mr. Morris reports that he considers the best systems are those in operation at Reigate and Oswestry. He gives the preference to Reigate for its greater simplicity, it being an oxidizing bacterial system, combining Candy Automatic Sprinklers and Intermitters upon Polarite beds.

"Karmal" Packing.

In the High Court, before Mr. Justice Farwell, on the 26th February last, the Frictionless Engine Packing Co. Limited, of Manchester, makers of the well-known "Karmal" engine packing, obtained an order against Bell's Asbestos Co., Limited, restraining them from applying the word "Karmal" to any engine packing manufactured by or for them.

Interesting to the Ice Trade.

The rapid development of the ice industry has created a demand for ice-crushing machinery that will supply large quantities of crushed ice at short

notice. A new illustrated catalogue is sent us by Messrs. David Bridge & Co., of Castleton, Manchester, dealing particularly with their specialities in connection with the ice trade. In it will be found descriptions of their power and hand crushers, ice elevators and conveyors, power and hand ice saws, ice tools of every description, power and hand overhead cranes, pulley blocks, monkey carriages, lifting tackle, patent superheaters and smoke preventing apparatus, automatic steam dryers, oil separators, oil filters, and steam cylinder lubricators, automatic water softening and purifying plants, etc. It is a useful booklet, and nicely got up.

"Little Giant" Pneumatic Tools.

The Standard Pneumatic Tool Company, of Chicago, manufacturers of the "Little Giant" air tools and appliances, have moved their New York office from 619, Washington Life Building, to more commodious quarters at 611, 612, 613, of the same building, this being necessitated on account of the very great increase in their business in eastern and foreign territory during the past few months. All shipments for customers in the district just mentioned will be made from New York instead of Chicago, thus expediting delivery of machines. Most of our readers are probably aware that the makers of these excellent labour-saving tools for Great Britain are the International Pneumatic Tool Co., of Westminster Palace Chambers, London, S.W.

Indicators and Pressure Gauges.

Owing to the increasing demand for their steam engine indicators, pressure gauges, and other steam specialities from London and the South of England, Messrs. T. S. McInnes & Co., Limited, have opened an office at 113, Fenchurch Street, E.C., and have also arranged for a stock being held at that address.

Galloways Limited.

We understand that Mr. Herbert Lindley, late of Browett, Lindley & Co., Limited, of Patricroft, has accepted the position of general manager to Galloways Limited, Manchester, who are taking up the construction of high-speed engines for electric installations.

Sanitation at Country Seats.

An interesting installation for purifying the sewage, slops, and refuse liquids from a country house in North Devon, designed by Mr. A. S. Goodridge, A.R.I.B.A., of Bath, has recently been put into operation, the analytical figures showing remarkable results, the effluent from the polarite beds being reported upon by the City Analyst as follows:— "I hereby certify that having analysed a sample of water received on the 4th day of January, 1901, from Mr. A. S. Goodridge, I find the same to contain the following:—

"Free ammonia	None.
Albuminoid ammonia (grs. per gallon)	·0028
Oxygen required to oxidize decomposing matters ...	None.

"This is a pure sample of water; no hesitation need be felt in using it for domestic purposes. It contains very small traces of soluble organic matter." These results were obtained by an oxidising bacterial bed composed of coke, sand, and 8 in. of polarite, the crude sewage having been merely passed through strainers and an open inoculation tank. It is all disposed of before any putrefaction takes place. The treatment, it will be seen, is of the simplest kind, the use of polarite enabling the sewage at a trifling expense to be converted into practically "pure water."

A Note for Electrical Firms.

In connection with their resistance materials and their speciality, "Beacon" wire, Messrs. W. N. Brunton and Son, Wire Mills, Musselburgh, Scotland, issue a booklet of more than ordinary value, inasmuch as it is believed to be the most complete list on resistance materials as used by electrical engineers that has yet been produced by any firm. It contains some most useful data, and should be filed for reference in every electrical engineer's office. The booklet is bound in a red cloth cover, and interleaved with a few blank pages, so that engineers using same may make any special notes of their own regarding resistances.

NEW PATENTS.

(Selections from recently published Patent specifications. Complete copies may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, W.C. Price 8d. each.)

No. 17,074 of 1900. L. Camont, of France, for "Metallic Packing for Stuffing-boxes."

The metallic packing consists of a ring or series of rings and intermediate washers of a suitable soft metal, with internal and external grooves, the form and depth of which are arranged to produce contact and tightness between the intermediate or flat parts of the packing and the shaft or rod, on the gland being tightened up by nuts of the stuffing box. The bore or internal diameter of the rings is larger than that of the shaft or rod, and the said rings are provided with lateral notches, in which a tool is adapted to be introduced, to allow of their easy extraction.

• • •

No. 17,182 of 1900. A. Riegel, of Paris, for "Speed-reducing Gear for Steam Turbines."

The speed-reducing gear for steam turbines and like high-speed motors consists in providing electro-magnetic drums on a receiving shaft, mounted parallel to the transmitting or turbine shaft, and providing the latter shaft, opposite the first-named drums, with drums or rollers fixed to it or integral therewith, a flexible and constant contact between the facing drums being ensured by means of flexible or elastic supports.

• • •

No. 491. "Petroleum Motors." R. Lucas, of Greenhall, Forest Row, Sussex. Dated January 9th, 1900.

In order to obtain an accurate feed of petroleum into the engine a needle valve is used, opened by the action of the vacuum, caused by the engine piston, on a diaphragm attached to the needle valve, and adjusted by the tension of a spring on the diaphragm. In order to entirely cut off the feed at any moment, this vacuum is released by opening the engine to the air by means of a valve.

EDITOR'S NOTE.

"Reviews of Books" have had to be held over owing to want of space. They will be resumed in our next issue.

LATEST TYPE OF EXPRESS ENGINE, GREAT WESTERN RAILWAY.

"Atbara" Class. Mr. W. Dean, Engineer.

The Engineering Times'

RECORD of

RAILWAY & TRAMWAY PROGRESS.

VOL. V. MAY, 1901. No. 5.

INTRODUCTION.

WE give expression to what we feel to be the general concensus of opinion when we say that to-day no matter is so powerful a factor in contributing to the welfare of nations and of communities as is that of transportation. The beneficial results which have followed the liberal extension of systems of locomotion are present wherever this enlightened policy has been judiciously acted upon.

The censorial sage, when he takes a general purview of these latter days and their commercial haste, shakes anxious head and apprehensively remarks, "All the world's in a hurry. Nemesis takes her walks within the wake!" But this hurry and this fever-heat within the lives of men, though not in themselves unmixed blessings, must be regarded as inevitable, and as the primal characteristic, perhaps only temporarily, of our evolving civilization. Men travel more to-day than ever they did before in the whole history of the world, and when men are trying to crowd two days' work into twenty-four hours the necessity for efficient and speedy transport from place to place is increasingly imperative, if modern conditions are to be coped with. The telegraph and the telephone have become part and parcel of every-day existence, but their development has never detrimentally affected the great systems of rail and road communication. Rather have they had an opposite effect, acting as a stimulus to still greater progress in locomotion, and in industry in general. Neither the efficiency nor the extent of the wire service has been such, we imagine, as to render it possible or politic for any pushing business house to "cut" the travelling expenses account. They who under-estimate the importance of giving adequate patronage to the modern systems of transportation, like those who pooh-pooh the policy of advertising, are bound to be the losers in the race, for do they not think to win astride a lame and panting steed while their rivals elect the evolation of the iron horse!

We English have well earned the appellation "the nation of shopkeepers,"

and to maintain that reputation and reap its accruing advantages we shall have to become more and more a nation of travellers. Is it not a fact that those who have gone the deepest into the question of our industrial supremacy have attributed our shortcomings, whatever they may be, as in a large measure due to our want of proper acquaintance with the developments taking place in other lands?

But it is hardly the present wish of the ENGINEERING TIMES to detail the manifold benefits which transport confers upon a people, whether socially, industrially, or from any other point of view. That is writ in letters of gold in the historic records of the progressive advance of the entire civilized world during the Victorian Era. Rather what we desire to do in this special Railway Number of our magazine is to indicate from the pens of eminent experts what are the matters of paramount import in connection with the rail and tramroad services of the world at the present moment, the latest difficulties and phases of so enormous a problem, and to bring forward some of the most recently devised means or suggestions for enabling locomotion authorities to give to the world something even better than their present best.

Steam Locomotion on Railways.

To us who are living in the United Kingdom at the beginning of the 20th century, in the first year of what promises to be the brilliant reign of His Majesty King Edward VII., it is difficult to even imagine what the position of our forefathers was a hundred years ago in relation to this matter of communications. The year 1801, without a single line of railway, had much in common with 4000 years B.C., when Pharaoh blundered with his chariots and horsemen into the Red Sea, and on a small scale this kingdom must have borne a certain resemblance to the land of the "Heathen Chinee" of to-day, a land rich in coal and mineral wealth, but without the transport facilities requisite to enable its own or any other people to turn them to account.

How true it is that the pioneering work of Trevithick, of Blenkinsop, of Hedley, and of Stephenson was the foundation stone upon which was to be raised a glorious edifice! But how true also is it that to a hundred subsequent workers of equal patience, and in the same field of practical research, we owe the thousand and one developments which have raised it from its primitive "Puffing Billy" condition of 1804 to the efficient condition in which we find it to-day!

From 1804 to the commencement of the Victorian Era, whose last and best and well-filled page we sadly turned over but a few short months ago, may rightly be regarded as the initiatory and experimental period. In fact, the growth and extension of our railways began just a few years before that Royal Lady ascended the throne. In 1830, it is true, the Liverpool and Manchester line was opened, but it was not until 1836 that railways became a subject of commercial speculation. In that year, however, the public became suddenly possessed with the idea that both industrial progress and social development would be furthered by building railways, and undoubtedly from that moment the United Kingdom entered on a period of mighty development. By 1844 some 2,000 miles were operating for traffic, and then it seems the flood-gates of speculation burst wide open. A mania, the like of which in the feverish frenzy of investors had not been seen since the days of the South Sea Bubble, possessed the kingdom. And where do we stand to-day as the result?

We do not propose to enter laboriously into statistical information, but it will be of interest to cite briefly the figures relating to English railways at the end of 1899, the latest figures available, we believe. The Board of Trade returns showed that there were 11,977 miles of double line, and 9,723 miles of single, or a total mileage of 21,700 in the United Kingdom. Upon these lines as many as 20,461 locomotives were working; the number of ordinary passengers carried was between 1,106 and 1,107 millions, and the minerals and merchandise conveyed represented nearly 414 million tons.

Sixty years ago, what were the figures? One thousand eight hundred miles, carrying eighteen and a half millions of passengers, and about five million tons of goods!

And we must not lose sight of the fact that all the great engineering and industrial progress of which we, as Englishmen, are so proud, has run concurrently with or followed quickly on the very heels of transportation developments. Surely may it be said that the railway, with its handmaid the telegraph, has brought the ends of the earth together, bringing man more into touch with man, and mind with mind! Those who are so inclined would doubtless find it a very interesting study to investigate the exact science of the responsibility of railway progress for all the other mental, moral, and social achievements of importance which had their birth during the period.

In the early days to which we have just referred England took a long lead in advance of the rest of the world. "Where do we stand to-day?" What is the position of the British locomotive builder, rolling stock, and other plant manufacturer in regard to the vast business which a peer through the curtain of the future shows us to be rapidly approaching? Sensational newsmongers may flap their wings if they will, and with a hue and cry spit sparks and tell all the world that the British manufacturer can't do this, can't do that, can't do the other. In some respects, perhaps, we have to admit "'Tis true, 'tis pity; pity 'tis, 'tis true!" but the manner of blasting forth the message is itself a stumbling-block. We fancy that these excited clamourings for cheap newspaper notoriety will do our railroad industries no good; rather will their effect be directly opposite. Close consideration, matured and deliberate opinions formed by the manufacturer himself, or by the expert railroad official—these are a thousand-fold more consequential and trustworthy, but unhappily their pronouncements are too often drowned by the cries of the excited sensation-seeker of the gutter-press stamp or complexion. Of the plain unvarnished truth the railway engineer is not ashamed, but these mangled untruths continually appearing in some daily papers concerning foreign competition make him blush for shame of the very tellers of them.

American and other foreign competition is undoubtedly a factor to be reckoned with, more particularly in the equipment of Colonial and Indian railroads (a section of the subject to which we shall refer directly), and general electrical engineering. But to say that engineering England is, in general, behind Germany, America, and other nations is foolishly untrue. Our shops are full with orders, and there is every indication that they are likely to remain so.

One point to which we think British locomotive builders should pay regard, in their own and our national interests, is the very serious one of boiler efficiency. As Mr. C. Rous Marten shows in his article on "Modern British Locomotive Practice," British made engines are still

unsurpassed in many important respects throughout the whole world, but in haulage strength they appear to be somewhat deficient. It is satisfactory to remember that a couple of years ago our engineers proceeded to build locomotives with more boiler power, but it seems that even now we have a considerable advance to make in this direction.

Liquid Fuel for Locomotives.

Fuel, to a steam railway, is its staff of life; but some of our eminent locomotive engineers are hopeful of better results by feeding them on liquids instead of solids. Nearly all locomotives running on English lines consume coal, but it is interesting to remember that liquid fuel is largely in favour in countries where there is a plentiful supply of petroleum, notwithstanding the closely competitive prices of wood and coal. This fact, in Mr. Holden's view, points to its efficiency and desirability. Fast trains are continually increasing the length of their runs, and one of the chief difficulties in connection with them is the fire, which has to be continuously urged, and, in consequence, becomes choked. Practical working on the Great Eastern Railway shows that with oil-burning locomotives this trouble does not exist, the supply of fuel being regular and continuous, and entirely free from residue. As an example of the actual results which he has obtained, it is noteworthy that one of Mr. Holden's engines was in steam some twenty-four hours without the fire being touched during the whole of the time. The enterprise of this English railway engineer is worthy of being closely watched by engineers of other lines.

Railway Enterprise in the Colonies.

Reverting to the general question of railways, it is interesting to take a glance at the present condition of railway communication in certain of our colonies and foreign dependencies. Give but a thought to our great Indian Empire with its teeming millions of population. It is true that there are many things in connection with the working of railways in that part of the world which one would like to see improved upon. The difficulties have been and are still enormous, but we have every confidence in the efforts which are now being put forth to hasten the dawn of better days. A work of such vast proportions will take many a long year, but the betterment of India is one of the great tasks which we shall master during the twentieth century, and in gaining that mastery material assistance will be rendered by locomotion. Happily there is a plentiful water supply in certain parts of that "Continent," and this will permit of the introduction of railways operated by hydro-electric installations in places where the fuel difficulty would have been very great indeed. No doubt before very long we shall pass the stage of mere conjecturing and scheming in this matter, and shall have long narrow-gauge railways such as the 180-mile Kashmir electric scheme—which has engaged the attention of the Indian Government for some time—in practical working. The problem of locomotion in India seems to be mixed up in an entanglement of a thousand other problems connected with the future well-being of such vast and peculiarly conditioned territory, but sooner or later, with the natural evolution of things, the advance of India will create enormous possibilities for the construction of standard and narrow-gauge lines.

The outlook in Africa is also worthy of mention. As a nation we have expended over a hundred and fifty millions sterling upon a conflict whose main object is now practically achieved. When the great territories affected are brought to a condition of lasting peace

and order, we may expect the existing and new railways to co-operate very largely in the evolutionary working out of great industries—industries such as our nation and our Empire must depend upon more and more as time goes on. For the time being, permanent railway progress in South Africa has been, of necessity, delayed, but herein we find an assurance that it may burst forth at a ten times greater rate when it becomes politic for us to stay actual hostilities. Farther north, however, there is nothing hindering English railway men in the working out of wonderful achievements. The Mombasa undertaking, the Cape-Cairo, and schemes of like importance, great as they are, may be described as practically the cutting of the first sod of a wonderful network to be laid down in all directions in the near future. In regard to Australia, the Philippines, Cuba, Russia, Manchuria, and so on, the same prospect is spread out, and these things are signs that the next generation or two will have an elephantine task before it, if railroads are to be introduced, as necessarily they must be if the world is to be opened out for commerce in accordance with principles to which civilized nations are professing adherence.

Application of Electricity on Railways.

Electrical engineers who have already applied electricity to the operation of short length lines are fondly hoping for the working of trunk railways by the same form of power. Railway men, on the other hand, though open to conviction when the practical proofs are available, are very sceptical upon the point. No one disputes for an instant the success which has accompanied the application of electrical working to the London underground railways, constructed on the "tube" system, and the very satisfactory results obtained on the Liverpool overhead railway likewise are not open to question, but the operation of long systems of heavy trains electrically is a very different problem. The managers and engineers of several of our great railway companies have quite recently been investigating the entire question, and we may confidently hope that within the next few years as electrical traction engineering develops, a decided advance will be made in electric railway working. The latest experience in America, Switzerland, Austria, and Italy seems to lend weight to this view.

Before we leave this section of our subject we cannot forbear reference to the great part played by the British nation in that very essential feature of our latter-day life in London—the underground railroad. When we call to mind the City and South London Railway of 1890, the first railway of its kind in the whole world, also the subsequently opened Waterloo and City and Central London systems, and when we remember that they have taught Americans and Continentals how to do this thing, we conjure up before us the form of one who went to his rest, as it seemed all too soon, in the year 1896. J. H. Greathead revolutionized our systems of tunnelling, and by his world-renowned shield made underground tube lines commercially practicable. To-day the world recognizes only in part what a great debt it owes to him. These underground railways are a tribute to the pioneering pluck of the British engineer, and when we say this, it is in presence of the fact that the electrical equipment of one of them is American. While the world is saying so much about what our rivals are doing, let it not forget what England has done and is still doing in this direction.

The Light Railway and the Tramway.

Up to this point our remarks have been devoted to heavy railway working,

but that is really but a portion of our subject, for the light railway and the tramway are to-day, in serving local needs, every bit as important. Tramway progress has not, however, forged ahead in this country with anything like that speed which should have characterized it. The Tramways Act of 1870 has stood in its way very seriously, a fact which most of those who have an interest in tramway enterprise are now endeavouring to drive home to the minds of our legislators. It was thought that the Light Railways Act of 1896 would lighten the burden of the promoter, and it is true that many a good scheme came forward. Some have got through, but municipal opposition and a variety of causes have militated against progress being made with many, with the result that to-day we find tramway authorities engaging in a very necessary agitation to remove at least some of their present legislative disabilities. The 1896 Act was supposed to apply to light railways, but any one who has watched what has followed under the administration of this Act is fully aware that many of the undertakings have been electric tramways pure and simple.

The question "What is a light railway?" is certainly a very interesting one, but we are afraid it is one as to which no really definite or general understanding appears to exist as yet. One piece of legislation which seems to be very necessary for the proper and fair development of tramway enterprises is an Act which, while conferring the advantages of the Light Railways Act as to time and cost, shall render it quite impossible for useful tramway schemes to be "scotched" purely because such and such a municipality whose area is touched affects to oppose. A modification of the municipal purchase clause is also a matter of urgency.

We find it difficult to agree with the views expressed by certain extremists that electric tramway progress has been delayed *mainly* because municipalities have chosen to take such work in hand. In nearly all the larger cities of the country extensive electric systems are in operation, or being rapidly laid down, and municipal money is spending very freely just now upon this very worthy object.

Electric Traction and the "Housing" Problem.

Electric traction and the "housing" problem are questions practically bound up together, and we venture to believe that if allowed free scope the former would go a very long way in the direction of solving the latter. To a great extent the relief should follow automatically upon the introduction of a wide-spreading network of cheaply operated electric lines running in all directions. With such a service the towns are bound to spread, and push the suburbs farther out, increasing residential accommodation. Sir Douglas Fox has had special facilities for investigating the problem, and he joins with Mr. Booth in emphasizing the urgent need for improved inter-communication between different parts of the metropolis and the suburbs. The operation of electric street cars and steam railways has, in several cases, been followed by a general movement of the working classes out to the areas covered by them. The underground electric railway schemes are conveying vast traffics, and others which are now constructing will find large business awaiting them when they are completed. A few months ago there appeared to be more or less of a mania for tube schemes, and if a fair proportion of those conjectured at that time are actually carried through there need be no fear of the great electric tram schemes of the London County Council being affected thereby, for every new line induces a large amount of traffic which did not exist before. One thing that is to be devoutly wished for is the hastening of the

electrification of the Metropolitan and Metropolitan District lines. On this and other cognate matters Sir William Preece has something to say in this issue of more than ordinary interest and value.

The Trolley and other Electric Tramway Systems.

Sir Douglas Fox sees nothing to object to in the overhead trolley wire method of working cars, as in vogue at Dublin, Liverpool, Bristol, and forty or fifty other places in this country. The objections once raised to it from the platform of æsthetic fancy have long been silenced by the practical operation of the system in these places on well-matured and efficient plans. For more central thoroughfares, whose already overcrowded state renders it essential that no method shall be introduced which may lead to additional obstruction, the trolley with its consequent poles and overhead work is considered to be quite out of the question. Where this is the case, if electricity is favoured as the motive power, open or closed conduits, or surface contact methods have to be duly weighed, and it is possible that eventually even the accumulator system may be practicable and find favour. In one or two Continental cities, within the town proper, batteries are employed, the overhead trolley being brought into play on the same cars where the suburban border is reached; but if uniformity of system for suburban and town transport is commercially practicable, it certainly is preferable to changing from one to another. So far as London is concerned an excellent system of trolley cars, owned by the London United Tramways Co., is now doing service in the western suburbs. The London County Council has decided to convert many of its horse-lines to the underground conduit principle in the busier streets, but in the suburbs it is intended that the trolley shall be made use of.

Other Mechanical Systems.

There are, of course, a number of other mechanical methods for the operation of street cars. Compressed gas, compressed air, running cable, and steam power are the systems which are to-day in practical working, though compressed air cars are not yet to be found on any English line. The main principles controlling their working are pretty familiar, and each system is claimed to possess its own special advantages; but any one who has followed the course of events in street-car propulsion during the past few years readily perceives that electric traction is the method most generally adopted to-day wherever speedy, frequent, and easily controlled street-car systems are needed.

The Question of Gauge.

One point of more than ordinary interest just now is the matter of uniformity of gauge. Much is being made of this, and there are many who fain would induce our rulers to render the adoption of one particular gauge compulsory on all parties. We venture to think that it is easier for a tramway to accommodate a town or district with a suitable width of line and car than it is convenient for the town authorities to demolish buildings and widen their streets to meet the width of the tramway. The cost of construction and equipment of standard gauge lines would render tramways out of the question for many places. On the other hand, a narrow gauge line for wide public thoroughfares in busy towns where millions of passengers are to be carried in the course of the year would often be a sheer absurdity. From the point of view of standardization of apparatus and car construction, to have uniformity of gauge is no doubt a distinct advantage; also in respect of a group of towns which require inter-communicating service over a large network, awkward

breaks and changes would be avoided. But a hard-and-fast line for the whole kingdom we are not in agreement with, and we are glad to observe that the Government has expressed its inability to make any such stipulation, although it recommends uniformity wherever it is reasonably applicable.

Electricity *v.* Steam on Suburban Railways.

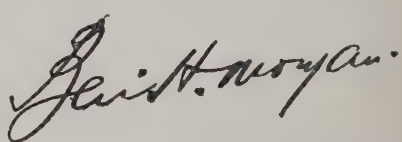
So far as the United Kingdom is concerned, the future extensions to our means of transport will consist of new tramways and light railways rather than in heavy railroad construction along enclosed ways. It is held by some experts that the existing branch railroads of the trunk lines will find the competition from these local electrical services somewhat embarrassing, and electric railway engineers forecast that for such suburban traffic these railway companies will call in the aid of electricity to help them to effectually meet the rivalry. There are many branch suburban steam sections which are far from being financially successful, even without competition, and for some of these the same conversion is anticipated. Polyphase transmission, the energy being distributed on one of the known third rail systems, possibly with multiple unit equipment for the various carriages, will doubtless be the method adopted; or the same distribution system with light weight electric locomotives as on the City and South London Railway may commend itself. The necessity for the protection of the third rail, or charged conductor, at public crossings ought not to be considered a material obstacle. Perhaps the Behr lightning express service, which seems to be nearing practical realization between Manchester and Liverpool, will be useful in this field.

Pioneering Work.

It is worthy of remark, before we say our final word, that it is between forty and fifty years ago since George Train was allowed to make a brief trial of his horse tramways at Westminster. He encountered much opposition of one kind and another, as all pioneers seem destined to do, and his rails had to be removed. But we look back upon Train's labours to-day with gratitude. No doubt in those earlier days his attempts procured for him the reputation of a maniac or dunderhead; in fact, even now there are a number of important English towns which we could mention which will not allow the "disfiguring" of their quiet streets by any kind of tramway whatsoever at any price. In most places, however, we are more enlightened, and are now making up for lost time as rapidly as possible. The progress of the next ten years will be considerably greater than that which we have witnessed since the first Westminster rails were removed.

Conclusion.

In these few pages we have covered a vast and varied ground, yet have been able to do no more than merely touch the fringe of this matter of locomotion and its development to meet the needs of the first years of the twentieth century. But if perchance, by this weak effort of ours, we have been in any way able to enlighten those who have favoured us with their silent company; or if in our recital of the brilliant progress of the past and brighter promise of the future we have been enabled, with the co-operation of our many eminent writers, to place a sign-post here and there in the byeways of the subject, then our duty will not have been performed in vain.



Editor.

CONTRIBUTORS.

1. Sir William H. Preece, K.C.B.
2. Sir Douglas Fox, Past Pres. Inst. C.E.
3. James Holden, M.Inst.C.E.
4. Prof. C. A. Carus-Wilson, A.M.Inst.C.E.
5. C. Rous-Marten.

Bernard Higham

CONTRIBUTORS.

1. J. G. White.
2. John P. O'Donnell.
3. W. G. Bagnall *(Photo. Elliott & Fry).*
4. G. L. Fowler.
5. J. Walwyn White.

BERNARD HIGHAM

RAPID TRANSIT IN LONDON IN RELATION TO THE HOUSING PROBLEM.

By SIR DOUGLAS FOX,
Past President Institution of Civil Engineers.

THE writer, having had exceptional opportunities for many years as a director of the Industrial Dwellings Company, Limited, of studying the problems of overcrowding, and of the best means of affording improved accommodation by those employed in the metropolis, is in full sympathy with the views now very generally expressed, that improved intercommunication between different parts of the metropolis and the suburbs is urgently required.

A most beneficent work has resulted from the efforts of Sir Sydney H. Waterlow, Bart., the late Mr. George Peabody, Lord Iveagh, Miss Octavia Hill, and others. It has been conclusively proved that, if unhealthy, overcrowded slums are cleared away, and a fair price only paid for their site, then, after reserving three-fifths of the area for playgrounds and open spaces, a far larger population can be well and comfortably housed, at no higher rents than were previously paid, and with the most excellent effect upon the health and morality of the community. The writer would urge that, in arriving at a fair purchase price for such sites, the neglect of the owners and lessees of the land in allowing the property erected thereon to become insanitary should be taken into account, and at least a considerable proportion of any loss from resale be made to fall upon them.

Taking the work of the company above mentioned alone, it has provided blocks of dwellings scattered over the metropolitan area for nearly 30,000 people, each tenement a complete house in itself, and fitted with the most improved sanitary arrangements. The average population in the area of greater London is about 60·9 per acre, the population on these estates, after setting aside, as above mentioned, three-fifths of the area for open space, is about 746 per acre. The average death rate of the metropolis is about 19·8 per 1,000, rising in slum districts to 40 and 50 per 1,000, whilst in these dwellings it stands at about 11·5 per 1,000, the birth-rate therein being somewhat below the average, or as 27·2 to 29·4 per 1,000.

It is not proposed to discuss at any length the proposition that the London County Council should provide dwellings for the superabundant population. The object is an excellent one, even if the methods adopted are open to criticism. It has hitherto seemed impossible for the public authorities to deal with this subject without throwing burdens upon the rates, which must tend to foster a most undesirable spirit of dependence and pauperism. It is agreed, however, on all hands, by those who have studied the subject, that the present condition of thousands of slum dwellings is a prolific source of disease, immorality, excessive drinking, and early death.

The ideal, for artizans employed upon manual labour, and therefore not requiring physical exercise to the same extent as do other classes, is that they should

live within half a mile of their work, have breakfast at home, work from 7.30 a.m. to 12 noon, if possible return home for dinner, and again work from 1 p.m. to 5 p.m., except on Saturdays. These hours, making 47 per week, have been adopted with great success in America, and are gradually being introduced into this country. The workmen's wives, who at first raised objections to this change of habit, are now convinced of the benefits of the new arrangement. Unfortunately, in a vast city like London, where property near the centres of work is so very valuable, this ideal cannot be attained.

Mr. Charles Booth has pointed out very forcibly, in his paper submitted to a conference held at Walworth, that improved intercommunication between different parts of the metropolis and the suburbs is absolutely necessary; but, whilst the London County Council may be the proper authority for tramways occupying the surface of the public streets, there are many and serious objections to such a public authority being entrusted with the construction and maintenance of underground tunnels, and the working of the traffic thereon.

The first great move towards rapid transit was the construction of the Metropolitan and Metropolitan District Railways, resulting in an extraordinary increase of locomotion amongst the working classes of the population, and producing, by their competition, that improved omnibus service which very soon followed, and which has been gradually brought to as high a pitch of speed and comfort as is practicable with horse traction.

It appears to the writer that an initial mistake was made (contrary to the expressed opinions of the then engineer of the Metropolitan Company, the late Sir John Fowler, Bart.) when junctions were permitted with the Inner Circle, and trains from the suburbs (belonging to various companies and introducing an element of unpunctuality, which with the best management cannot be altogether avoided) were allowed to intermingle with the local service. It may be hoped that, with the too long delayed, but now impending introduction of electrical working on these two railways, may be combined the stoppage of all suburban trains at the nearest points of junction with the Inner Circle, and the construction at such points of well-considered exchange passages such as now exist at King's Cross and Baker Street, by which passengers can readily pass from the outer to the inner system, and *vice versâ*. As practically very little luggage is even now carried by the through trains, this exchange would cause but slight inconvenience, and would result in a saving of time even to and from the suburbs, whilst the Inner Circle service could be remodelled and immensely improved. With electric traction, upon the "multiple unit," or some similar system, much more rapid acceleration and retardation can be effected (thus increasing the average speed, including stoppages, from 12 miles, as at present, to probably 16 miles per hour). Shorter trains with better means of entrance and exit than in the carriages on the present Metropolitan system, and an increased number of block sections, would result in its being perfectly practicable on this circular route (where no shunting is necessary) to run trains every 2½ minutes each way during the busy hours, with a much reduced pressure at the stations, as compared with that which results from the present large train capacity and longer interval. Even this improvement, added to the construction of the authorised "deep level" electrical line under the present tunnel from Earl's Court to Mansion House, would only partially meet the requirements of the densely populated districts served by the Inner Circle.

The District Railway is now extending from Whitechapel to Bow; but unless this branch is worked by exchange, it will increase the difficulties of a frequent service.

A new era opened when the City and South London Railway Company began to run its trains, followed by the Waterloo and City Railway Company, and, only last year, by the Central London Railway Company.

The system of construction of cast-iron tunnels deep down in the London clay, far below all cellars, sewers, drains, gas, and water-pipes, combined with the "shield" method of driving, followed by the "Greathead" plan of grouting under pressure to reduce settlement to a minimum, rendered these railways practicable from an engineering point of view.

The report of the Joint Committee of both Houses of Parliament, which fully considered the subject in 1892, rendered them financially possible by recommending that they be allowed to pass under the public streets without payment (in consideration of cheap workmen's trains being provided), and that, where they run under private property without interfering with the surface, the companies should only be required to pay a reasonable sum for the easement, and not be compelled to purchase surface rights and good-will, which in London are of so costly a nature as to be prohibitive.

This Committee expressed general approval of the following lines then proposed—

Great Northern and City Railway;
Central London Railway;
City and South London Railway;
Waterloo and City Railway;
Baker Street and Waterloo Railway;
Hampstead, St. Pancras and Charing Cross Railway (now the Charing Cross, Euston and Hampstead Railway),

as being required to relieve the overgrown passenger traffic along the chief thoroughfares, to provide for the natural expansion of London, and to check the congestion of our metropolitan population by facilitating cheap communication outwards to a circumference which tends constantly to recede. The Committee intimated that, in their opinion, these railways were only an instalment of what would be required to provide complete accommodation to meet the constantly increasing need of London, and they added the following very important remark, to which an interval of nearly nine years has given increased force: "More such lines of communication are required with existing suburbs; and there is growing need of their extension still further into the country, in order to meet the increasing necessity for the removal of portions of the population to a greater distance."

Since the date of that report, the following railways have been sanctioned:—

The North-West London Railway;
The City and Brixton Railway;
The Brompton and Piccadilly Railway;
The Great Northern and Strand Railway;
The Deep Level District Railway.

Adopting very low fares, a frequent and absolutely punctual service, and convenient rolling stock, combined with electrical working (thus avoiding the bad condition of the atmosphere due to the products of combustion from the steam locomotives on the Metropolitan system), the three railways already opened have proved a distinct advantage, especially to the working classes.

Experience has, however, developed certain points upon which great improvements can be introduced into the railways upon this system already authorised, and about to be constructed, in order to still further improve, by a system of mechanical ventilation, the

atmosphere in the tunnels, and, by strengthening the permanent way and avoiding concentrated load on driving wheels, to prevent the vibration in adjoining houses, which has created considerable opposition on some parts of the Central London Railway, where it runs near valuable residential property.

The diameter of the tunnels on the straight has been already increased from 10 ft. on the first section of the City and South London Railway to 11 ft. $8\frac{1}{2}$ in. (or a minimum of 11 ft. 6 in.) on the Central London Railway, and 12 ft. $2\frac{1}{4}$ in. (or a minimum of 12 ft.) on the Waterloo and City Railway. In order, however, to facilitate the introduction of the "multiple unit," combined with a well-proportioned rail and ample headway in the carriages, a further increase probably to 12 ft. 6 in. minimum on the straight is necessary, and it is to be hoped that the Joint Committee appointed to consider the railway bills for London this Session will deal with this question, although it is now too late to establish absolute uniformity.

The City and South London Railway, at present $5\frac{1}{2}$ miles long, although hampered by the small size of its original tunnels, and the consequently cramped dimensions of its rolling stock, has been the pioneer of this class of railway, and most of the initial difficulties arising in the introduction of new principles of construction and management have been overcome by its able engineers and manager. It has proved an immense boon to South London, and will shortly be extended to Brixton. Its extension to the "Angel" at Islington will confer similar advantages on the northern side of the river.

The Waterloo and City Railway, $1\frac{1}{2}$ miles in length, which passes under the Thames, carries an increasing traffic between the Waterloo Terminus and the City, for which it was specially constructed. It has, however, no intermediate stations, and does not therefore benefit the district through which it passes. A station at Blackfriars would be a distinct improvement, as also the provision of lifts, at any rate at its City terminus, where passengers have now to walk from a depth of some 65 ft. below the street level.

The Central London Railway, $6\frac{3}{8}$ miles long, running from Shepherd's Bush to the Mansion House, has evidently catered for a distinct want, as its traffic has been most satisfactory from the commencement, and is steadily increasing. It serves most important centres, such as Notting Hill, Lancaster Gate, Marble Arch, Bond Sreet, Oxford Circus, Holborn, Chancery Lane, and the Post Office, and its system of lifts and trains has been most admirably devised to ensure punctuality and comfort to the passengers. The Company has followed the example of the Liverpool Overhead Railway in adopting a uniform rate of 2*d*. per passenger for whatever distance. In Liverpool, however, the traffic is chiefly to and from the two termini from and to the centre, and therefore the average distance travelled is less than in London, where, at the busy hours, the trains are chiefly occupied with passengers travelling the whole distance or nearly so. Whether, under these circumstances, a uniform fare will answer, and whether the exclusion of a first-class carriage at a higher fare as adopted in Liverpool will prove satisfactory, can only be tested by actual experience.

Another important tunnel railway is in course of construction, and now well forward, viz., the Waterloo and Baker Street, $5\frac{3}{8}$ miles in length, which, starting from the "Elephant and Castle," and passing through Waterloo Station and under the river, will give stations, amongst others, at Charing Cross, Piccadilly Circus (with an exchange with the Brompton and Piccadilly and

the Piccadilly and City Railways), and Marylebone Terminus of the Great Central Railway, Edgware Road (with an exchange station there with the North-West London Railway, to be hereinafter described), and Paddington Station.

The Great Northern and City Railway, $3\frac{1}{2}$ miles in length, running from near Finsbury Park through Highbury and under the New North Road to Finsbury Pavement, is also well advanced towards completion. In view of the possibility of this line being used hereafter for through passengers and for goods traffic, the tunnels are being constructed with an internal diameter of 16 ft., a dimension sufficient to accommodate main line rolling stock.

The works on all these railways have been carried out without any material damage to property, except in a few cases in sinking the station shafts, and in putting in shield chambers preparatory to starting the actual shields. Considering all the surrounding circumstances, this is a fine achievement on the part of the engineers and contractors concerned.

There are at the present time authorised, but not yet carried out, the following tunnel railways within the metropolis.

The Charing Cross, Euston and Hampstead Railway, 7 miles in length, the contract for which has been let, and which, commencing under the Charing Cross Station of the South Eastern and Chatham Companies, gives stations at Cranborne Street, New Oxford Street (exchange with Central London Railway), Tottenham Court Road, Euston Road, Euston Station (exchange with London and North Western Railway), "Mother Red Cap," Chalk Farm, Adelaide Road, Belsize Lane, and High Street, Hampstead, with a branch under the Camden Road to the Kentish Town Station of the Midland Railway. This railway will supply a north and south connection, which has been long called for, and is now to be supplied through the enterprise of American capitalists. This Company is applying for certain extensions to Golder's Green and Highgate.

The Great Northern and Strand Railway, $6\frac{1}{3}$ miles in length, which will run from Wood Green under the main line of the Great Northern Railway to King's Cross, and thence under streets and private property to the new street in course of construction by the London County Council. It will be constructed under that street to the new Crescent adjoining Wellington Street, Strand, and will form an important north and south connection lying between the Charing Cross, Euston and Hampstead and the Great Northern and City Railways.

The North-West London Railway, $4\frac{1}{8}$ miles long, which, commencing at Cricklewood, will run for its whole length under the Edgware Road, providing four intermediate stations, including the exchange station already mentioned with the Waterloo and Baker Street Railway, and will terminate at a station at the Marble Arch, in direct connection by subway with the station there of the Central London Railway.

The Brompton and Piccadilly Railway, $2\frac{3}{8}$ miles in length, which, commencing at the South Kensington Station of the District Railway and connected therewith by subway, will run chiefly under the Brompton Road, Knightsbridge, and Piccadilly, to near Piccadilly Circus. This Company is seeking to extend its line under Shaftesbury Avenue for about a mile to a connection with the Charing Cross, Euston and Hampstead Railway, and with the Central London Railway.

Assuming that the figures given in a very interesting table by the *Railway News* are approximately correct, and

allowing for certain lines which have been withdrawn, it appears that the above tubular railways when completed will represent a total length of about 58 miles of double line, of which $13\frac{3}{8}$ miles have already been finished and opened to the public. The total estimated capital for these lines, including both shares and debentures, is approximately £30,000,000, or an average of about £520,000 per mile for Parliamentary expenses, land, works, stations, electrical equipment and rolling stock, interest during construction, and administration.

The capital powers vary from about £600,000 per mile for the Central London to £328,000 for the "deep level" line of the District Company, which requires but little additional property.

In addition to the above, seven proposals of new companies are before Parliament, and are to be submitted to a Joint Committee of the two Houses, which, whilst taking care that private interests are sufficiently protected, will, it is to be hoped, avoid the insertion of such burdensome clauses as would have the effect of preventing capitalists from finding the funds wherewith to construct such of these lines as the Committee may approve. The necessarily high cost of these underground railways is quite sufficient for the Companies to bear, without being hampered with conditions, the extent and risk of which are uncertain. It would certainly be a calamity to Londoners if at least the more important of these proposals are not passed this year.

The Charing Cross, Hammersmith and District Railway, 5 miles in length, would run from Hammersmith, under Hyde and Green Parks and the Mall, to Charing Cross. It would thus compete severely with both the Brompton and Piccadilly and the District Railways.

The King's Road Railway, nearly 3 miles long, would serve the S.W. district, bringing it into communication with the District Railway at Victoria.

The Piccadilly and City Railway, nearly 2 miles in length, is proposed to form an extension westward of the Brompton and Piccadilly Railway, and, if worked in conjunction with this and the District system, would prove an efficient substitute for the authorised "deep level" line already described, and would at the same time provide stations for the public convenience at Piccadilly Circus (exchange with the Baker Street and Waterloo), Lowther Arcade (exchange with the Charing Cross, Euston and Hampstead, and the South Eastern Railways), a siding for the traffic of Covent Garden Market, Wellington Street (exchange with the Great Northern and Strand Railway), Chancery Lane (subways with the Law Courts and Temple), Ludgate Circus and Cannon Street (exchange with the North-East London Railway). This additional east and west connection appears to be one of the most urgent needs of the metropolis.

The North-East London Railway, nearly 11 miles in length, is intended to connect both with the Piccadilly and City Railway and also with the Deep Level Railway if this be constructed, and will provide stations at the Monument (exchange with the Inner Circle and with the City and Brixton Railway), at Liverpool Street (exchange with the Central London and Great Eastern Railways), and at several intermediate points, with termini respectively in the important and rapidly growing suburbs of Tottenham and Walthamstow. It is also to be so laid out, as, if the Great Eastern Company approve, to form a relief line for some of their heavy suburban traffic. It would bring the densely-populated districts through which it would run into close touch with Epping Forest.

It will also provide the necessary

rapid transit for the 42,000 people who are to be housed at Tottenham by the London County Council.

The City and North-East Suburban Railway, over 16 miles in length, would occupy the same route as the North-East London Railway for a considerable distance. It would serve Victoria Park (to which extent, if worked in harmony with the North-East London, it might be a useful branch of that line), but beyond the Park it would interfere seriously with the public playing fields, and would run for many miles through open country not yet ripe for development. Its tunnels are proposed to be only 11ft. 6 in. in diameter, which experience proves to be too small.

The Islington and Euston Railway, $1\frac{5}{8}$ miles in length, would form a valuable connection between the "Angel" at Islington, the City and South London Railway, and Charing Cross, Euston and Hampstead Railway, as well as with the London and North-Western Railway.

The West and South London Junction, $4\frac{1}{2}$ miles long, runs from Paddington, under the Edgware Road, where it would seriously compete with the North-West London Railway, and thence under Park Lane to Victoria and Vauxhall.

The estimated capital, including both shares and debentures, for these seven lines—nearly 43 miles in length—is a little over £19,000,000, equal to about £450,000 per mile.

It will be seen, therefore, that, after much delay, the wants of the metropolis, as regards these railways dealing with longer distance traffic rather than with local passengers between intermediate stations somewhat near together, is in a fair way to be supplied, and this without any important destruction of surface property and the consequent displacement of the population.

The existence, at a moderate depth, of the London clay, a most excellent stratum for shield tunnelling, enables these lines of communication to be established at the minimum of risk and disturbance, and clear of all complications or interference with subways near the surface, deep basements, and other requirements of civilization.

The adoption of complete insulated circuits for the electric currents, which is now intended on most of the lines in course of construction and proposed, will obviate any electrical interference with telegraphs and telephones, and will prevent electrolytic action upon water and gas pipes. The arrangement now happily arrived at after practical experiment between the London United Tramways Company and the authorities of the Kew Observatory proves that the difficulties previously experienced have been overcome.

The tunnels will no doubt be mechanically ventilated so as to remove air vitiated by the large number of passengers passing through them, and increased attention will be paid to the efficient lighting both of stations and rolling stock, to more rapid acceleration on starting, and to improved brake arrangements.

Automatic electric signalling, as introduced and now most successfully worked for many years on the Liverpool Overhead Railway, will greatly facilitate and ensure the safety of a $2\frac{1}{2}$ or 3 minutes' service.

By means of these railways, and of the cheap trains for workmen to be run thereon, the artizan will be enabled to live in the suburbs, and yet to be within half an hour of his work, by a service, constant, punctual, and free from the interruptions which take place on the overground railways, however well managed, from climatic influence—especially fog—and from the necessity of intermingling trains from varying distances, through and local, on the same lines of rails.

It must not, however, be considered

that either the improvement of the Inner Circle, or the completion of this network of railways, deep down below the streets, will meet all the wants of the metropolis.

Large masses of the population desire to be carried from their very doors and only for a short distance, a service at present performed by omnibuses, whose rapid multiplication has greatly increased the block in the streets and their insanitary condition.

Partly owing to obstructive legislation, and partly because of a well-grounded dislike of overhead wires, the introduction of electric tramways has been delayed for years, so that the metropolis is not only far behind American cities, but has been out-distanced by Dublin, Leeds, Bristol, Liverpool, Manchester, Glasgow, Cork, and even by Dover and many smaller towns. There is now, however, a prospect that the antiquated omnibus, with its long-suffering horses, and the resulting serious nuisances, will disappear from the main thoroughfares, and that commodious, well-lighted tram-cars, running with perfect safety at a much higher speed, and occupying much less space in the street in proportion to their capacity than the omnibuses, will take their place. These will then efficiently deal with short journey passengers.

No one can study, as the writer has had occasion to do, the working of the Dublin and of the Liverpool Electrical Tramways, and the wonderful use made of them by all classes of the population, without being convinced of their paramount utility for that purpose, and also of the fact that, so far from interfering with the general traffic of the streets, they assist and regulate it. It may be hoped that the London County Council will not much longer be compelled, as in the present year, by the opposition of various boroughs, to withdraw some of its most important proposed lines from the consideration of Parliament. The conflict upon this question of tramways which has taken place between County and District Councils, in Surrey and elsewhere, has much to answer for in preventing the artizan class from securing the cheap and rapid locomotion which they so urgently desire.

Several proposals have been made for improving the present condition of matters as regards the congested traffic of the metropolis, to which brief reference may be made.

There have been at least two suggestions of a radial system of tubular railways from a central station to the various suburbs and to the respective goods stations of the railway companies. If it were a question of laying out a new city to meet present requirements, a system of that kind running under broad avenues might be advantageous. It has, however, been conclusively proved more than once before Parliamentary Committees that such a concentration of traffic in a city like London with narrow streets would only make matters worse. Very little of the goods traffic actually dealt with in the goods stations is for through transmission; the bulk of it has to be carted to warehouses, depôts, and shops, for distribution throughout the metropolis.

The Parliamentary Committee of 1863–64 reported against any central station in the metropolis, and was of opinion that the goods traffic could best be accommodated by railways running round London, and picking up the great terminal stations of the main lines of railway.

These suggestions at any rate come too late, as, in view of the extensive system of tubular railways already constructed, in progress, or sanctioned, it is evident that any further railways of the kind must be so laid out as to feed and exchange with them at convenient points in different parts of the metropolis,

and not necessarily in or near the centre thereof.

It has been well proposed, by Sir John Wolfe Barry, K.C.B., that the London County Council should lay out several more arterial thoroughfares of ample width, making use as much as possible of new connections between back streets which would be thus formed into continuous avenues. With this suggestion might well be combined that of Sir Frederick Bramwell, Bart., that elevated footways, such as in the Chester Rows, should give access to an upper row of shops, being connected at intervals by footbridges; and the further one of the Rt. Hon. Arthur J. Balfour, M.P., that in these wide thoroughfares motor-car omnibuses might run at cheap fares.

The idea of subways just beneath the surface of the streets, whilst most practical and important, if limited to the size necessary to accommodate gas and water mains, and telegraph and telephone cables, and which, if circular, could be driven by shield and could be kept well away from the foundations of the houses, would, if designed to accommodate the heavy street traffic, be found impracticable on account of their cost. Being necessarily, if they were to be of any use, of a width which would occupy a large proportion of the space between houses in many of the streets, and being constructed in the made ground and water-bearing strata above the London clay, they would involve the underpinning of the houses, and even then would inevitably cause serious structural disturbance, whilst the whole of the surface drainage, and the gas and water supply, would have to be remodelled.

It would appear therefore that the pressing necessity, not for the working population only, but for all classes, that the congestion of the streets should be relieved, may be best met:—

(*a*) By re-organising the Inner Circle system and establishing a continuous service of short interval trains thereon, passengers to or from the suburbs passing from or into these trains at the nearest point of interchange.

(*b*) By carrying out the authorised tubular railways with tunnels not less than 12 ft. 6 in. in diameter inside, and effecting exchanges between them wherever practicable, probably under a system of transfer tickets.

(*c*) By Parliament sanctioning, as a further instalment of a complete system, such of the pending Bills as may be found to meet the present requirements, subject to proper exchange stations being arranged with existing lines.

(*d*) By utilising the more important side streets as portions of additional main thoroughfares.

(*e*) By constructing subways to carry the gas and water pipes and telegraph and telephone cables, so as to render the present constant interference with the surface of roadways and footpaths no longer necessary.

(*f*) By introducing electric tramways, either on the conduit or some other approved system, in many of the main thoroughfares of the metropolis; omnibuses drawn by horses to be thereafter excluded from such thoroughfares.

PROGRESS IN ELECTRIC TRACTION.

By Sir WILLIAM H. PREECE, K.C.B., F.R.S., etc.,

Past President of the Institution of Civil Engineers.

ELECTRIC traction on existing railways has not yet made any marked progress anywhere, but its success on tramways and in underground railways has created a "boom." Electric railways originated in the United Kingdom. The first was to the Giant's Causeway from Portrush in North Ireland in 1883. Next came the City and South London, opened in 1890. The next was the Elevated Railway along the line of the Mersey Docks in Liverpool, in 1893. Then the Waterloo and City opened in 1898, and finally in 1900 the Central London, which has proved so disastrous to the traffic of the Metropolitan underground lines that the two companies affected have decided to equip their lines electrically as speedily as possible.

It is remarkable that the United Kingdom, which has proved to be the pioneer in nearly every electrical industry, should have fallen back so seriously in the race. America, Germany, France, Switzerland, and Italy are before her. Some attribute our backwardness to restrictive legislation, others to the absence of technical enterprise; but I am strongly of opinion that it is due to financial considerations. The Tramways Act of 1870 certainly retarded the introduction of tramways *per se*, but not in any way their electrical working. The Electric Lighting Act of 1882 was a most valuable Act, placing the supervision of electrical industries on a solid legal basis, and giving the Government, through the Board of Trade, a most wholesome supervision and control. It made electrical energy a commercial article, and regulated its manufacture and sale. It was rendered necessary by the great financial boom of 1879–81, when speculation was rampant and disastrous. The public lost millions in the wildest schemes, and our financial purse-holders were forced to tie up their purses, which they have not yet re-opened. Railway and Traction companies have had to go to New York for capital to electrify their lines. I have known many valuable schemes put by for the want of financial support. The fact is too patent that the British financier has lost faith in electrical enterprises at home, and the electrical engineer has to look to the United States and Germany for financial help. This is the cause of our national backwardness, and not legislation or technical inability. Money is not forthcoming for the utilization of electric energy. We are suffering from the financial fiasco of twenty years ago.

Electricity has several marked advantages over steam traction. It enables the energy required to drive the train, to be generated in fixed buildings, where water is abundant and fuel cheap, and where every known invention conducive to economy can be applied. On a locomotive itself a horse-power hour requires a consumption of about 7 lb. of coal. In a modern up-to-date power-house it can be produced for $1\frac{1}{2}$ lb. of coal.

The power required to drive the train

is limited on a steam locomotive by the size and weight of the engine, by the pressure of the steam, and by the rate at which the steam flows through the ports. With electricity the driving power can be distributed upon every coach and upon every axle. The weight even of the passengers can be utilized for traction purposes. There is no idle or useless weight. Hence the trains are not only lighter, but they acquire their speed with so much greater acceleration that they gain their mean rate of running in a much quicker time. There is also the fact that the application of steam power is reciprocating and pulsatory, while that of electric power is continuous and uniform. On railways the acceleration by steam rarely reaches 6 in. per second per second, but with electricity 1 ft. 6 in.—the limit allowed by the comfort of the passenger—is obtained easily. The consequence is that the time of running of the Inner Circle trains of our Metropolitan railways around the Circle, which is now 70 minutes, will be only 50 minutes.

The gain of mean speed due to this increased acceleration is of immense consequence in a traffic like that on the Metropolitan lines, which is always starting, coasting and stopping, and rarely, if ever, running at full speed; but even when we have long clear lengths, as in working express traffic, the constant application of a continuously applied unlimited driving-power upon every wheel enables such speeds to be attained as are beyond the dreams of the most progressive railway manager. There will be no difficulty in obtaining 110 miles an hour on the projected Manchester and Liverpool monorail express railway.

But the most important consequence of these merits is that cheapened energy, lighter trains, and quicker service mean reduced working expenses per train mile, and greater capacity for carrying passengers. They attract a new and unanticipated traffic. Passengers on the South Western Railway who arrive at Waterloo to go to Bond Street, take the Waterloo and City electric line to the Royal Exchange, and then the "Twopenny Tube" to Bond Street, and thus gain time, economy, and comfort.

It is estimated that on the Metropolitan lines the working expenses per train mile could be reduced 30 per cent. and the carrying capacity increased 35 per cent. with the existing rolling stock. But with new stock and with new working appliances practical with electrical energy it is difficult to estimate the possible carrying capacity. I am quite sure that electrifying the Metropolitan lines will stagger the railway humanity. There can be no doubt that the financial condition of these lines will be resuscitated and their lost traffic recovered. The secret of the success of electric traction is quick transit, rapid service, increased comfort, and cheap fares.

The locomotive mode of working trains peculiar to steam by placing at the head of the train a heavy motor which pulls the passenger coaches, has, in some instances, survived even on electric lines. The City and South London Electric Railway, and the latest electric line in London, the Central London, or "Twopenny Tube," are so worked. Apart from losing the chief advantages of more distributed motive power, and adding much unnecessary weight to the train for adhesive purposes, this system has the defect of concentrating a much greater portion of unspring-borne dead weight on one spot, to hammer and pound the rails, creating noise, vibrations, and unnecessary wear and tear of the permanent way. These effects have been so serious on the "Twopenny Tube" that an important committee, consisting of Lord Rayleigh, Sir John Wolfe Barry, and Professor Ewing, has been appointed to inquire

into their causes. Their labours have not yet ended, and their report is not issued. The more modern mode of working originated on tramways, and in a modified form was introduced on the Liverpool Elevated Railway by Mr. Parker, who designed and carried out the electric equipment of that line in 1892. Every train then consisted of two coaches, the head and tail bogies were motor bogies, and the middle bogies were unequipped. The trains now consist of three coaches, the two outer ones being motor coaches, the other a trailer. Thus the motive power is more distributed and the train can be run in either direction. There is no shunting or changes of position of car, as are required in locomotive working. This system has been adopted in the best practice in the United States, and it has been well elaborated and worked out by Mr. Frank Sprague, who calls it the "multiple unit system." On this system a train is made up of units, each unit containing a motor-car and one, two, or three trailers. (A coach used solely for motive purposes is called a *locomotive*, one carrying passengers as well as motors a *motor-car*, and one carrying passengers only a *trailer*.)

The train is thus very elastic. It can run in either direction. It can be made up of any number of units, all of which can be controlled from one point, which is always at the head of the train.

The Central London Railway Company has ordered from the General Electric Company of the U.S.A. an experimental train fitted up on the multiple unit system, and its performance will be watched with great interest, for it is hoped by it to remedy the vibrations that are now causing so much trouble.

It has been the practice in the United Kingdom and in the United States to work electric lines, tramways, and railways by direct continuous currents, and by a concensus of experience the voltage has been limited to 500 volts at the motor. This limit has been determined by the question of security to human life, for until recently no case was on record where a man had been killed by 500 volts. Higher voltages are dangerous, and indeed impractical, when brushes, commutators, and broken circuits are dealt with and handled. Some distressing cases have recently occurred where death has resulted on 500 volt lines to men working on the permanent way, but how far the voltage is the cause or some secondary effects due to intense currents is not clear. Anyway, a third rail between the two running rails, the common mode of equipping a line originated on the Liverpool Railway, is a source of danger. Experience shows that in our London tubes it would be safer to put the conductor over the train at the top of the tunnel rather than below it, as is now the practice. It would then be inaccessible to the permanent way men. But the use of such enormous currents as heavy trains demand when working with 500 volts seems to preclude the possibility of doing this with continuous currents. It wants higher pressures with their smaller currents. Alternating currents can be safely distributed at 3,000 volts, and in consequence the size of the conductors can be reduced one-sixth. Instead of using 600 amperes the alternating currents require 100 only. Thus overhead trolleys become possible.

The use of 3,000 volts frightens many people. But danger does not depend on voltage. I have frequently received with impunity shocks from induction coils and Leyden jars giving 40,000 volts and more. Safety is a question of engineering. It depends on the construction of the apparatus, on the freedom from sparks, and on the impossibility of the human frame touching live

conductors or accidentally forming part of the circuit.

The use of high-pressure alternating currents and overhead trolley wire affect advantageously the electrical methods of working of railways in other ways besides securing safety by placing the live conductors out of reach.

In the first place the present series-multiple system of control of the motors in use with continuous currents, is replaced by what Messrs. Ganz term a "cascade" system. This consists in connecting at first starting the stator winding of the main motor on one driving axle to the feeding conductors, and the rotor winding to the stator winding of a second or subsidiary motor on the other driving axle of the same bogie, the rotor winding of which is connected to a liquid resistance. This resistance is automatically reduced and then cut out as the speed of the train increases to half the maximum speed. At this half-speed the subsidiary motors are cut out and the rotors of the main motors connected to the resistances, which are in turn gradually and automatically reduced to zero as the speed increases to the maximum. The effect is to give a practically unlimited starting torque, and to obtain at once the maximum desirable acceleration.

The only work done by the wattman or driver is first to connect the live conductors to the main motor, and, secondly, to cut out the subsidiary motors when half speed is reached. As both these movements are worked pneumatically the driver stands in no danger of obtaining shocks from the conductors. The passengers are safe under all circumstances.

Another advantage with this cascade system of working is that the braking of trains is much simplified, three-quarters of the work being done electrically by reversing the starting connections and connecting the main motor, whilst running at full speed, to the subsidiary motors, and thus making them generators. This, by inducing a great retarding force, quickly brings the train down to half speed, returning energy the while to the line. The air brakes are thus required to reduce the train from half speed to stop only, supplying the other quarter of the brake work and saving much wear and tear of the brake blocks and of the tyres of the wheels.

The next advantage in the use of alternating currents supplied to a train is that it dispenses entirely with all moving machinery and therefore staff in the sub-stations. Where the current is generated as well as supplied at 3,000 volts no sub-stations at all are required. Where, owing to the distance over which the energy must be transmitted, a higher initial voltage is necessary, the sub-stations contain only static transformers, which require no continuous personal attention.

Another advantage with alternating currents is that the motors are simpler in construction and more robust than continuous motors—they have no commutators. They are easily and safely controlled under high pressure. With these motors also it is possible to so attach them to the axles that the whole weight is springborne, which, as already pointed out, would save wear and tear of the permanent way, check vibration, and reduce noise. A great advantage on lines with many gradients is the fact that three-phase motors run at constant speed whatever the grade or weight of the train. This could not fail to be of considerable advantage where rushes of traffic are occasionally encountered, for notwithstanding the large increase of the weight of the train on such occasions they would maintain the time table without difficulty. Although delays at stations could not be made up, there would be no loss of speed whilst running, and trains need never be more

than a few minutes late at the busiest time. One important advantage of alternate current working is that it entirely eliminates all those electrical disturbances that have so much excited our gas and water authorities. There would be no electrolytic pitting of metal pipes. There would be no difficulty in complying with the most stringent protecting regulations of the Board of Trade, and of the so-called "Observatory Clauses."

It must, however, be pointed out that by the use of a metallic circuit, as was done on the experimental line between Earl's Court and High Street, Kensington, continuous currents became equally freed from producing disturbing effects. These disturbances arise principally from the use of the earth, and the earth becomes unnecessary with two insulated conductors.

The economy of equipping a line with an alternating instead of a continuous current would not be less than 40 per cent. in capital expenditure, while there would be a considerable reduction in working expenses. It seems a system eminently adapted for working long lines. Indeed, it seems the only practical method of doing so.

One disadvantage with the use of three-phase working is that three conductors are required instead of two as with continuous current. Or assuming the running rails to be used as one conductor, two conductors must be placed overhead as against one insulated rail on ground level.

There can be no doubt that for tramways, from which up to the present our only experience as regards overhead conductors has been obtained, two overhead trolley wires are extremely difficult to deal with; but this is only because of the many sharp curves, turn-outs, crossings, etc., that must be met with on tramways. These difficulties practically disappear on railways. Points are met with fairly frequently, but they are easily managed. The Valtellina Line, near Lake Como, is now being equipped on this system by Messrs. Ganz, and we shall soon have a real practical test of this apparent advance in electric traction.

Another disadvantage with three-phase currents is that a loss is occasioned in the mains and motors due to the power factor or lag of current behind the voltage. This at times has amounted to as much as 15 per cent., but it is much reduced by the fine clearances now obtainable by modern machine tool methods. This affects the size of the dynamos, motors, and mains, but not the steam plant or the working expenses. This increased cost, however, is as nothing compared with that of the rotary converters and sub-station equipment required with continuous currents.

Looking into the future, the next great development of electric traction will certainly be in the direction of the working the various suburban services around London and other great cities. The great improvement already shown by the present imperfectly worked "Tubes" in dealing with rushes of traffic has already impressed railway managers. It is fairly evident that all that can be done in suburban working by steam has been done, and the result is still congestion, delay, and dissatisfaction.

Electric traction can quicken the service, as already pointed out, by increasing considerably the rates of acceleration. It can very much reduce the congestion at termini by eliminating the locomotive, thereby also eliminating the shunting which causes much of the trouble at present. With electric working trains run into a terminus, the wattman has only to walk to the other end of the train, and it is at once ready to start on another back journey. If the busier hours are over, the train can

be divided into two or more parts, leaving one or more portions shunted at the terminus until the rush of traffic begins again. A general saving of time, power, and worry would of a certainty result, and the capacity of the lines would increase. Heavy race traffic would be dealt with with greater facility, and general economy result.

Another very important development of electric traction which will give astonishing results in the near future is the adaptation of electricity to the extra high speed working of railways.

In this case, also, steam has done practically all it can do. The space required for a steam plant, and the weight of the same, limits any steam-drawn train to speeds of a possible 80 miles per hour. With electricity there is no such limit. On the proposed Manchester and Liverpool express line, to be constructed by Mr. Behr on the monorail system, cars weighing about fifty tons and carrying as many as 100 passengers will connect the two towns in 20 minutes, travelling at the rate of 110 miles an hour with certainty and safety. Notwithstanding the additional power required, the working expenses per ton mile will be less than upon ordinary steam railways. The comfort of the passengers will be increased, and the cost of travelling decreased.

The most interesting electrical question of the present day is whether our main line railways can be converted into electric lines. This question has been most ably dealt with lately by Mr. Langdon, electrical engineer of the Midland Railway, before the Institute of Electrical Engineers, and by Major P. Cardew in a series of Cantor Lectures at the Society of Arts.

It is a well-known axiom that to work steam railways economically the trains should be loaded as much as possible, and run at long intervals.

On the other hand, with electrical working, the aim is to run the trains at as short intervals as possible, so as to obtain an even load on the generating stations. It is obvious that such a system would give far greater satisfaction to the public than the former. An ideal railway service is to be able to go to the nearest station at any time of the day and to catch a train going in the direction we want to go within a few minutes.

There can be no doubt, therefore, that electricity can be made far preferable to steam for passenger traffic, whether express, slow, or suburban.

A very important question affecting the quick transit of trains has been brought out by the experience of electric traction. It is the length of stops at stations. This had brought into prominence the difference between English and American coaches. The stops on the Metropolitan railways average 35 seconds, and on the "Twopenny Tube" at first they were as low as 15 seconds. This is attributed to the difference in the coaches, but it is really due to the abolition of classes. On our steam railways passengers wander up and down a train to sort themselves into first, second, and third class, smoking and empty carriages. In the American car they sort themselves inside the train. The English compartment can be filled and emptied with much greater rapidity than the American long car with one entry at one end and an egress at the other. If railway companies adopted an exit platform and made the up and down platforms entries only, and if they abolished the classes, then a train of English coaches need not stop more than 10 seconds. Electric traction and American success are driving us to this consummation, which is devoutly to be wished.

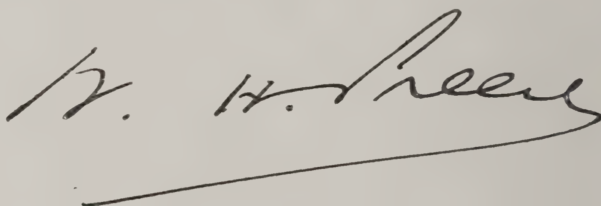
Major Cardew in his Cantor Lectures worked out the cost of equipping a section of line; 99 miles of double line would not exceed £8,000 per mile, excluding

motor-cars and rolling stock, including generating station and all sub-station equipment. This was allowing three-quarter hour services of heavy suburban trains, a half-hourly express service, and half-hourly local trains over the system. The total train mileage throughout the 24 hours, if the service were maintained for that length of time, would work out at over 9,000 train miles per day (the weight of train averaging 200 tons), or 3,285,000 train miles per annum, an average of about 33,000 train miles per mile of double line.

In 1898 the London and North-Western Railway had 1,908 miles of line open, and the train mileage for the year was 47,548,652, an average of 25,000 train miles per mile of line.

The London and South-Western Railway, Great Eastern and Great Northern Railways also average about 20,000 train miles per mile of double track.

A similar equipment, therefore, to that proposed by Major Cardew would certainly be adaptable to these lines, and the cost, therefore, of equipment would be about £7,000,000 to £8,000,000, and another £3,000,000 at the most for motor-cars and rolling stock.



POLYPHASE ELECTRICAL TRACTION.

By Prof. C. A. CARUS-WILSON, A.M.Inst.C.E., M.Inst.E.E.

FOUR polyphase railways are at present in operation, all, as the accompanying map shows, in Switzerland. The most important is the Burgdorf-Thun Railway, which is twenty-five miles long, and forms a link connecting the main railways radiating eastwards from Berne. The power house is situated at Spiez, on the lake of Thun, from whence the three-phase current is taken by overhead wires at 16,000 volts, and distributed at 750 volts to the two trolley wires which span the track, the reduction being effected by transformers placed along the route. The line is laid to normal gauge, so that it can carry the ordinary steam-driven

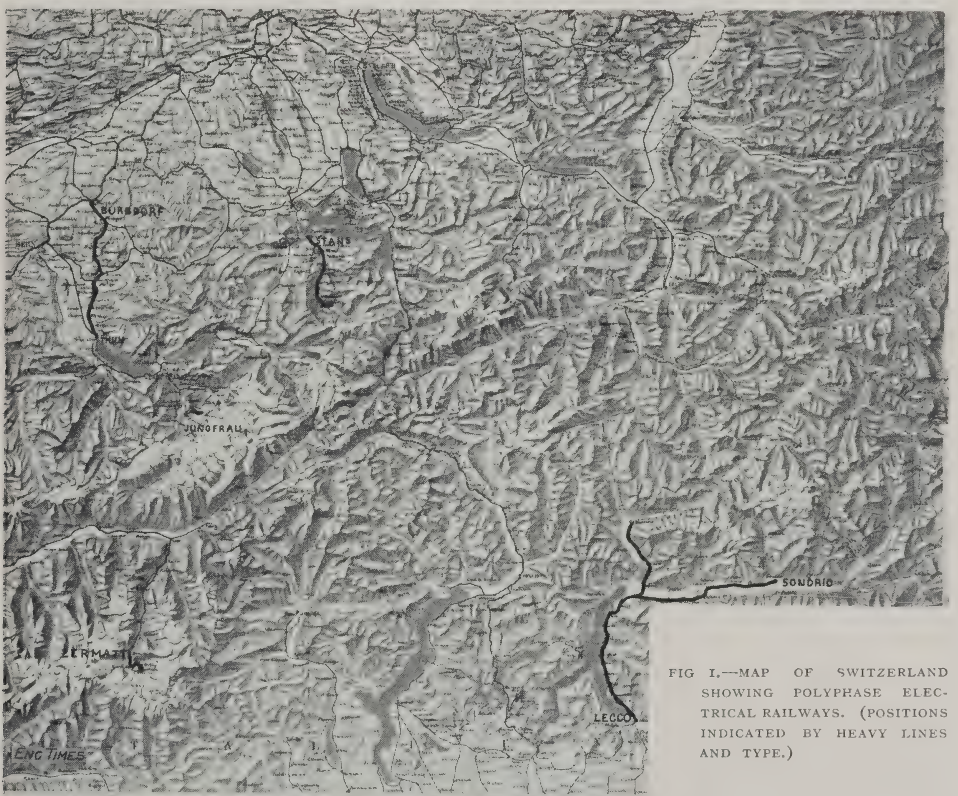


FIG I.—MAP OF SWITZERLAND SHOWING POLYPHASE ELECTRICAL RAILWAYS. (POSITIONS INDICATED BY HEAVY LINES AND TYPE.)

rolling stock of the other railways to which it is connected. The passenger trains, travelling at twenty-four miles an hour, are drawn by motor-cars, while the goods trains are drawn at half that speed by locomotives. Connections are made at Burgdorf, Konolfingen, and Thun with nearly all the passenger trains leaving Berne for the east.

Next in importance to the Burgdorf-Thun Railway is that connecting Stans, on the Lake of Lucerne, with Engelberg. This line is fourteen miles long, with one mile of rack. Motor-cars with trailers travel up and down at twelve miles an hour, while on the rack section a specially designed locomotive pushes the train at three miles an hour up a grade of one in four. A view of one of these locomotives is given in Fig. 2. Two 75 h.-p. polyphase motors are mounted on one truck, and drive the central pinion which engages in the rack. The metal cylinder over the motors contains the rheostat used in starting. Fig. 3 shows a locomotive and motor-car descending the incline.

The rack railway from Zermatt to the Gornergrat is a continuous rise of one in five for about five miles. A view of one of the stations, with a train in readiness to descend, is given in Fig. 4. The locomotive is scarcely distinguishable from the train, as the car is made to rest on it, in order to obtain greater weight on the rack. These locomotives are similar to those used on the Engelberg Railway, but are rather more powerful.

The Jungfrau Railway has attracted great attention on account of the boldness of the enterprise. The project is to pierce a tunnel six miles long through the rock, starting from near the Scheidegg, and terminating immediately beneath the summit of the Jungfrau, the rise in that distance being 7,000 feet. About half a mile of tunnelling and a mile and a half of approach have been finished and successfully operated. Current is brought from Lauterbrunnen by three overhead wires at 7,000 volts, and taken on to the trolley wires at five hundred volts. The whole line is laid out with a rack, up which the cars are pushed by locomotives, one of which is shown in Fig. 5. Two

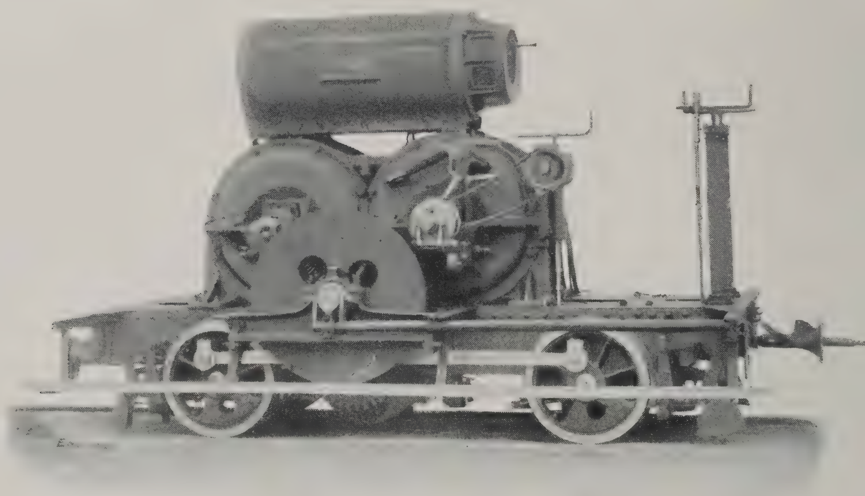


FIG. 2.—POLYPHASE ELECTRIC LOCOMOTIVE USED ON THE RACK SECTION OF THE STANS-ENGELBERG LINE.

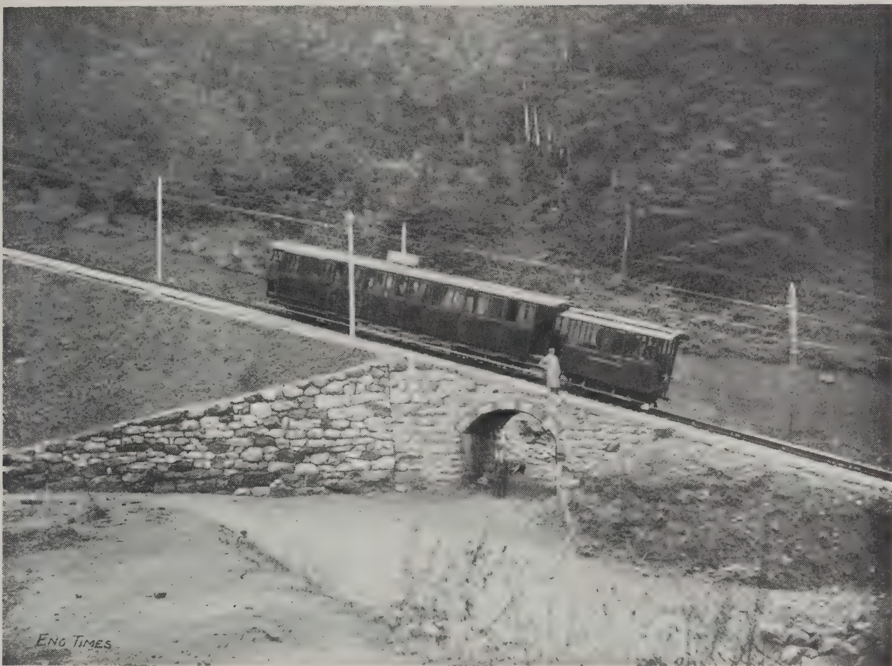


FIG. 3.—VIEW SHOWING A TRAIN DESCENDING AN INCLINE ON THE STANS-ENGELBERG RAILWAY.

FIG. 4.—VIEW SHOWING A TRAIN AND STATION ON THE ZERMATT-GORNERGRAT LINE.

polyphase motors, each of 200 h.-p., drive the pinions which engage in the rack. In the figure the top of one of the motors is removed, exposing the helical gearing. In Fig. 6 a locomotive and car is seen descending the incline opposite the Eiger glacier.

The only instance of the use of the polyphase system for street tramways is to be found at Lugano, where several miles of line have been in successful operation for some years. As three conductors are necessary, it is the usual practice to provide two trolley wires and a return by the main rails. This arrangement gives rise to complications, especially at crossings and turn-outs, and no doubt this feature has militated against the system being introduced for use on tramways.

The railway which runs from Lecco to Colico on the Lake of Como, and branches thence to Chiavenna and to Sondrio in the Valtellina, is at the present time being equipped with electrical traction on the polyphase system. The work will be completed and ready for operation this summer, and will furnish a valuable illustration of the conversion of a railway from steam to electrical traction. The whole length of the line is sixty-six miles, a considerable portion of which is heavily graded. The current will be generated at 20,000 volts by a water-power installation at Morbegno, and carried overhead to sub-stations and thence to the trolley wires, which will feed directly into the motors at a tension of 3,000 volts.

Polyphase currents have been almost universally adopted for transmitting power from a central generating station to different points of an electric railway system in those cases where a definite saving could be effected by concentrating the generating plant at a single power-house. Thus, for example, on the Central London Railway the power is generated at Shepherd's Bush, and sent in the form of three-phase alternating current at 5,000 volts to sub-stations situated along the line.

It is at the sub-stations that the characteristics of a polyphase railway, properly so called, begin to make their appearance, and the determining factor in the question is whether direct or alternating current motors are used on the trains.

If direct current motors are used, the alternating current received at the sub-stations has to be converted into direct current. One type of converter has the appearance of an ordinary direct current generator, being in reality an alternating motor and a direct current generator in one. Another type takes the form of a combination of a distinct motor and generator. In both cases the converting mechanism has to be kept continuously rotating, and needs constant and careful attention. The direct current delivered from the sub-stations is led on to the trolley lines by the usual feeders, and thence to the direct current motors.

If alternating current motors are used, the high tension current from the power-house is transformed in ordinary static transformers to a lower voltage, suitable for the trolley wires, from which it is led direct into alternating motors on the trains. The use of rotating apparatus in the sub-stations, with its initial first cost, upkeep, and liability to breakdown, is thus avoided.

The advantages attending the use of an alternating motor for railway work were for a long time counterbalanced by the vital objection that a single-phase motor would not start up on a load. It was, in fact, in the same plight as a single-acting steam-engine, in that it possessed the undesirable feature of dead-points. This difficulty has however been overcome by the expedient

of placing two or more alternating circuits at suitable angles to one another, much in the same way in which two or more steam-engines are combined for the same purpose; but with this difference, that in a steam-engine the force, with uniform steam pressure, varies according to an harmonic law, and it is not possible to get a perfectly uniform turning moment by combining two or more such forces; whereas the force generated by each phase of a polyphase motor has the remarkable property of producing an absolutely uniform turning moment when combined with two or more similar phases at suitable angles.

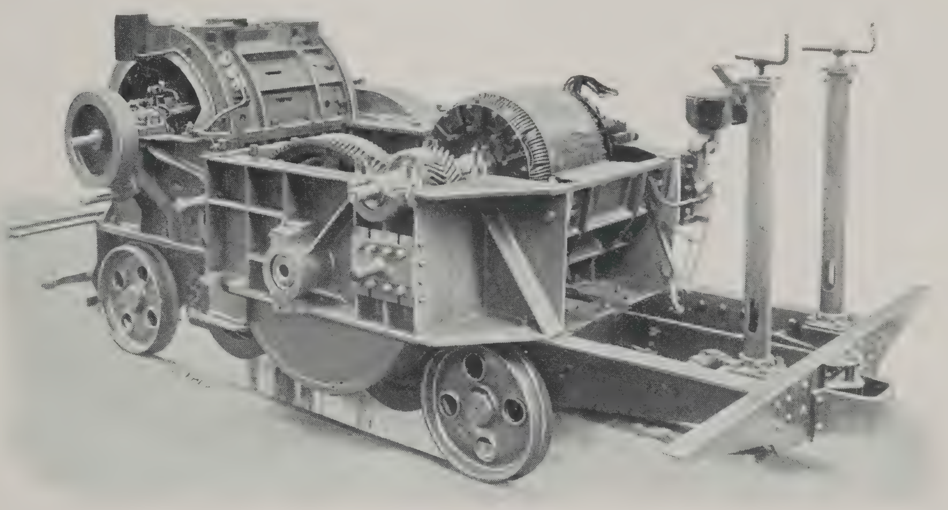


FIG. 5.—POLYPHASE ELECTRIC LOCOMOTIVE USED ON THE JUNGFRAU RAILWAY.

The relation of the rotor of a polyphase motor to its stator is practically that of the secondary of a transformer to its primary, with the exception that in the motor the two parts must be free to move with respect to one another. This means a mechanical clearance between the two, so that a certain width of air as well as the iron in the motor has to be magnetized. Since air does not, like iron, absorb energy when rapidly magnetized and demagnetized, a powerless current has to be provided to magnetize it, that is, a lagging current out of step with the volts in the primary. This means, practically, that to work a polyphase motor we have to supply not only the current actually required to do the work, but also that required to magnetize the clearance. Although this current does not involve an expenditure of energy, the generators, transformers, motors, and the whole transmission system have to be made large enough to carry it as well as the true power current. For example, on the Valtellina Railway the useful current is 80 per cent. of the total current at half load, so that the capacity of the whole system has to be 25 per cent. greater than is actually required by the work to be done.

It is thus necessary to reduce the clearance as much as one can consistently with safety. This is a much more difficult thing to do in a railway motor than in one which can be bolted down on to a firm foundation. In spite of this, very small clearances have been used on the Swiss polyphase railways with perfect immunity from accident. Thus on the Burgdorf-Thun Railway, the

64 h.-p. motors on the motor-cars have a clearance of about the sixteenth of an inch, while the 150 h.-p. motors on the locomotives have a clearance of three-sixteenths of an inch. It speaks well for Messrs. Brown, Boveri & Co.'s design and construction of these motors that they have worked without any trouble since they were installed. The fact remains, however, that in spite of all that can be done to reduce the lagging current, the total current has to be about 25 per cent. greater than the power current.

The feature of the polyphase motor which will probably have the greatest influence on the question of its applicability for railway work is that its speed is determined by the number of alternations of the current, and not by the tension. Thus with an eight-pole motor and a frequency of forty alternations per second, the speed of rotation will be 600 revolutions per minute, and will be quite independent of the voltage. This affects vitally the whole problem of railway working.

It is, of course, of great importance for many reasons to be able to raise the tension on the trolley wires. When we attempt to do this with direct currents, we are at once met by the difficulty that by raising the volts on the trolley wires we increase the speed of the motor, so that in order to keep the speed of the train the same as with a lower voltage we must do one of three things. Either we must decrease the diameter of the driving wheel, or put on a larger gear wheel, or increase the size and strength of the magnets. But the size of the gear wheel is limited by the fact that it must clear the rail level with a given sized driving wheel, so that we cannot reduce the diameter of the driving wheel or increase the gear wheel beyond a fixed limit. Neither can we increase the size of the magnets beyond a certain point, on account of the limited space available. The result is that the mechanical difficulties involved prevent our raising the volts on the trolley wires of a direct current system much beyond the usual 500 volts, and this quite apart from the question of the difficulty of designing a motor that would be satisfactory as regards insulation at higher voltages.

With alternating current motors, however, the case is quite different. The volts on the trolley wires may be raised to any desired amount, but if the frequency is kept the same, the speed will be unaltered. In this way the advantages of high tension transmission can be secured throughout the whole system, not only on the main line feeders, but also on the trolley wires. For example, the trolley wires on the Valtellina Railway already referred to will have a tension of 3,000 volts, and will be connected directly to three-phase motors on the trains working at that tension.

High tension motors are not, of course, an essential accompaniment of high tension on the trolley wires, since it is possible with alternating motors to reduce the tension on the train by means of transformers. This method has been adopted by the firm of Siemens and Halske, who, together with the Allgemeine Elektricitats Gesellschaft and Messrs. Borsig & Co., of Berlin, have made a large number of experiments on the application of polyphase currents to railway working. The employment of transformers on the train introduces additional apparatus, rendering a locomotive almost a necessity, the advantages of the arrangement being a low tension on the motors, and also that additional transformers with varying ratios of reduction can be used to get greater torque at starting.

Since the speed is determined by the frequency, a train driven by polyphase motors will run at a constant rate

independently of load. This is a feature of importance on those lines where a rigid adherence to the schedule time is essential, as for instance on a line where the hours of departure and arrival are timed to fit in with the service of trains on two or more main lines. With direct current motors, the speed in such a case may vary considerably with the load, and serious delays ensue. For example, a train consisting of one motor-car driven by direct current motors might run at twenty-one miles an hour on a level; but if the load were doubled by the addition of two trailers, the speed might fall to seventeen miles an hour. If the train were being driven by polyphase motors the reduction in speed would be imperceptible.

This constancy of speed, however, has its drawbacks when the line is laid out with considerable gradients, a great increase of power being required to mount the grades at the same speed as when running on a level. With direct current motors the speed falls off as the grade increases, so that the speed on a grade is considerably less than that on a level, and thus much steeper grades can be negotiated without overloading the motors. For instance, if a 16-ton car driven by polyphase motors, working at their full capacity, could climb a grade of 5 per cent. at twenty miles an hour, direct current motors of equal horse-power could carry the same load at fifteen miles an hour up a grade of 7 per cent.

FIG. 6.—SHOWING A LOCOMOTIVE AND CAR DESCENDING AN INCLINE OPPOSITE THE EIGER GLACIER.

The prejudicial effect of a constant speed on a line where the grades are heavy is well illustrated in the case of the Burgdorf-Thun Railway. The grades on this line vary considerably, and in some places are as much as one in forty; the passenger traffic is carried by motor-cars of 250 h.-p., weighing

thirty-two tons each. With the existing grades the load that can be hauled over the line by each motor-car is limited to a single 12-ton trailer. If the grades had not exceeded 1 per cent., each motor-car could have taken with it four more trailers, making five in all, thereby more than doubling the seating capacity of the train. As it is, if there are more passengers than can be carried on a motor-car and one trailer, a second motor-car has to be added. But the grades have a still greater effect on the goods traffic. This is drawn by locomotives of 300 h.-p., weighing thirty tons. Owing to the grades the load behind the locomotive is limited to twenty tons, and it has been found necessary to reduce the speed by gearing to one half that of the passenger cars, in order to be able to increase the load drawn to seventy tons. If the maximum grade had not exceeded 1 per cent. the existing locomotives could have hauled this load at full speed. The limitation imposed upon the traffic by the grades is very detrimental to the successful working of this line, and it would probably pay to reconstruct that portion where the grades are heaviest.

On the Valtellina Railway the grades of course are already fixed, and in places are as much as one in fifty. Messrs. Ganz & Company, who are installing the electrical equipment, have designed an arrangement to meet the difficulty of the abnormal grades. The passenger trains weigh sixty-five tons, and are made up of motor-cars and three or four ordinary railway trailers. Each motor-car carries four three-phase motors. When running on a level, two motors of 150 h.-p. each are used; but when going up an incline of anything over 1 per cent., the second set of motors will be put in tandem with the first set, thereby halving the speed, the power remaining the same. The goods traffic on this line is to be drawn by locomotives of 600 h.-p. each, weighing about forty-five tons. The total weight of the goods trains will be 250 tons, and they will have to travel at half the speed of the passenger trains. This arrangement must interfere considerably with the service. Generally speaking, the rigidity of the polyphase system in the matter of speed places it at a disadvantage, when compared with continuous currents, on lines where the gradients are severe and constantly varying.

In those cases where steam traction is being changed over to electrical traction, the grades, such as they are, must of course be accepted as a disagreeable necessity. But when a line, such as the Burgdorf-Thun Railway, is constructed in the first instance for electrical traction, the adoption of heavy grades is a mistake, especially if the polyphase system is to be used.

The ability of polyphase motors to get up speed has often been questioned. It has been stated that these motors give very little starting torque, that they might do very well on a long line where they had a chance to run at a uniform speed, but that where the whole process consisted of starting and stopping, they would be of little use when compared with continuous current motors.

In the autumn of 1899 the writer made a series of tests on the Burgdorf-Thun Railway to ascertain this point, and settle the question definitely. Trains consisting of a motor-car and trailers were made up of different weights, and observations were made of the energy required to get up a given speed from rest, and the time occupied in so doing. The results compared favourably with the performance of a continuous current equipment under similar conditions. The polyphase motors used rather more energy than continuous current motors, but they took a smaller maximum power

from the line, on account of the favourable disposition rendered possible by the large number of poles used.

More recently Messrs. Ganz & Co. have adopted with success the principle by which two polyphase motors can be put in tandem at starting, thereby securing an increased efficiency, and putting the polyphase motor very nearly on an equality with the direct current motor in the matter of efficiency of starting. But Messrs. Ganz have gone further than this, and have utilized the tandem principle for stopping the trains. By this method the train is started by two motors in tandem; at half speed one motor—the auxiliary—is switched out, and the train brought up to full speed by the remaining motor. To stop the train the auxiliary motor is put in tandem with the other, and current thereby returned into the line. This current retards the train until half speed has been reached, when the process can be continued no longer, and the train is then brought to rest by mechanical brakes. In this way three-fourths of the energy of movement of the train can be returned as current into the line, instead of being lost in grinding up the brake blocks. By this arrangement, which was proposed for the London Metropolitan and District Railway, the polyphase system uses less energy than the continuous current system in covering a given distance in a given time from start to stop.

FIG. 7.—VIEW SHOWING WORKMEN ENGAGED IN BONDING RAILS ON THE VALTELLINA RAILWAY.

It is somewhat remarkable that the first practical suggestion for saving the energy of motion of a train by returning it as current into the line instead of wasting it on the brake blocks should have come in connection with a traction scheme on the polyphase system. There is however nothing to prevent the same principle being used with still better results with continuous current motors, and a scheme has already

been brought forward, and was referred to by Major Cardew in his Cantor Lectures this spring, by which one-third of the energy used in running trains with frequent starts and stops, as on the Inner Circle, is recoverable by returning current into the line.

The greatest possible efficiency for starting and stopping would be attained by using a variable speed gear, if such a thing were available. Now in the continuous current motor we have the precise equivalent to a variable speed gear in field variation. Thus a series-wound motor with a field variation range, say, of two to one will start and run a given distance in a given time for 40 per cent. less energy than that required by a motor with constant strength of fields. But no method of varying the field in a polyphase motor has yet been discovered; it is therefore at a disadvantage when compared with a continuous current motor in which the field can be varied both for starting and stopping. The range with ordinary railway motors, as at present used, is not much more than one-and-a-half to one, but when this is increased to two-and-a-half or three to one, the direct current motor can be made to start and stop with less energy than the polyphase motor.

The characteristics of the polyphase system appear then to be high trolley voltage, constancy of speed, absence of commutators and rotary converters, a double trolley, a lagging current, and a constant field.

Looking to the future, the evidence goes to show that the polyphase system will not supersede the continuous current system for urban traffic, since in work of this kind the area is more or less confined, and the high trolley voltage and absence of rotary converters are advantages which scarcely outweigh the disadvantages of the double trolley, the lagging current, and the constant field.

For inter-urban and long distance lines, however, this balance of disadvantage is reversed, provided the gradients are moderate, for in that case a fixed field is no objection, and the constancy of speed becomes a valuable feature in securing punctuality in the train service. The ability to handle large variations of load over long distances with a rigid adherence to the timetable is the really valuable feature of the polyphase system. To do this economically the grades must be favourable; but where this is so the polyphase system has great potentialities.

Chas A. Carus Wilson

LIQUID FUEL ON THE GREAT EASTERN RAILWAY.

By JAMES HOLDEN, M.Inst.C.E.,

Locomotive Superintendent Great Eastern Railway.

THE employment of liquid fuel on some of the locomotives of the Great Eastern Railway was originally due to the successful results obtained from experiments made with waste oil-gas tar products under stationary boilers; the apparatus has been perfected and adapted to the varied requirements of railway locomotives in ordinary daily running. At the present time most of the fast express trains between London and the principal seaside resorts of the popular East Coast of England are hauled by engines using liquid fuel.

Of the many attempts that have been made to utilize liquid fuel on locomotives and stationary boilers in Great Britain, the majority relied on the provision of apparatus and furnaces similar to those which have been found suitable in Russia and America, where petroleum has been largely employed as fuel for many years, and where a constant supply is obtainable at reasonable prices as compared with coal, which is dear there.

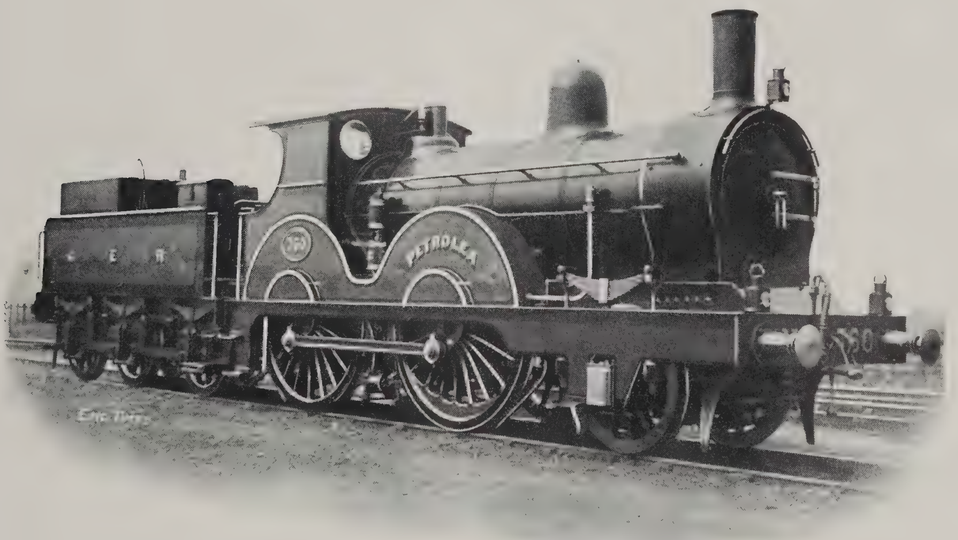


FIG. I.—THE FIRST OIL-FIRED EXPRESS LOCOMOTIVE ON THE GREAT EASTERN RAILWAY.

The Great Eastern apparatus has been so devised that it is possible to apply it to ordinary coal-fired boilers and furnaces without alteration to the existing details, and to fire an engine so fitted with either coal alone, oil fuel in conjunction with the coal, or entirely with liquid fuel. To accomplish this, the author's apparatus is designed to not only effectually atomize and

distribute the liquid fuel spray, but also to induce atmospheric air to support the combustion of the oil independently of that admitted to the ordinary fire by the ashpan and its open dampers.

The first locomotive to be fitted to burn oil fuel on the Great Eastern Railway was a six-wheels-coupled shunting tank engine, having cylinders $16\frac{1}{2}$ in. diameter by 22 in. stroke, with driving-wheels 4 ft. diameter. A series of experiments was made with this engine late in 1886, running on the main line between Stratford and Broxbourne, with trial trips of newly-built vehicles. Only one burner was applied to the fire-box of this engine (281), placed just below the footplate, about eighteen inches above the fire-bars; and a coal fire of about twelve inches thick was maintained on the grate. The ordinary fire-brick arch was retained, as also the air deflecting screen in the fire-hole. The engine was very satisfactory in its performances, provided it was not unduly forced; but when it became necessary to urge the fire beyond a certain limit, it was found that the distribution of the fuel spray and the consequent heating of the fire-box was unequal and insufficient. More burners were therefore arranged for in the next locomotive fitted, a four-wheels-coupled double ender passenger tank engine. Four burners were at first employed, two at the front, and two at the rear of the fire-box; and the sprays from these being opposite to each other, it was expected that a much better distribution would result from conflicting jets than was actually experienced. The consumption of oil fuel was high, the engine steamed indifferently, and, further, the number of valves and pipes necessary for supplying four burners was objectionable. After a few days' service, the two burners at the tube-plate end of the fire-box were removed, and the holes blocked, resulting in a considerable improvement in the working, the two burners at the front maintaining steam easily on a very moderate consumption of fuel, and the fire presenting a brilliant appearance.

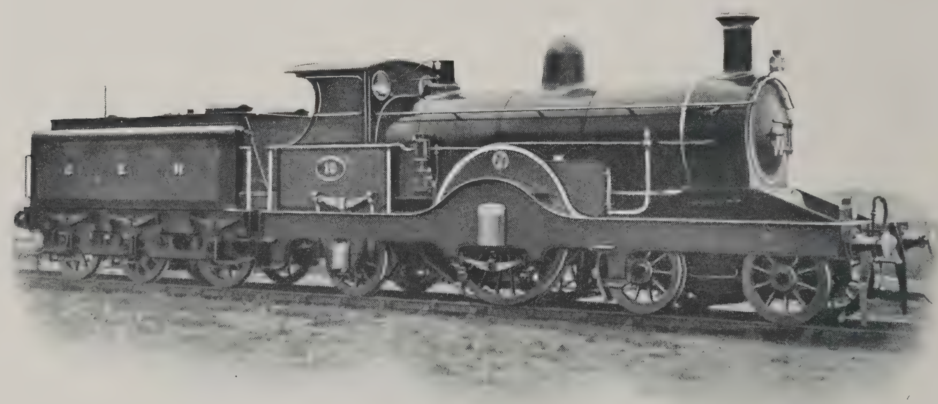


FIG. 2.—SINGLE-WHEEL EXPRESS PASSENGER LOCOMOTIVE GREAT EASTERN RAILWAY.

Superheated steam and compressed air were both tried on this engine for spraying the oil fuel. With the former, the continual trouble with the pipes, fittings, and superheating devices more than discounted any slight advantage; and with the latter, the disadvantages of additional machinery for compressing the air became too apparent to justify extended employment.

From the working of this engine a

modified arrangement of the apparatus was devised and applied to an express locomotive (760), which has been working satisfactorily now for the past ten years, running a total of some 350,000 miles. This engine is represented in the photograph (Fig. 1), and is of a type introduced by the writer soon after taking charge of the locomotive department of the Great Eastern Railway. The chief dimensions are: cylinders, 18 in. diameter by 24 in. stroke; drivers, 7 ft. diameter; and leading wheels, 4 ft. diameter. The boiler has 1,230 sq. ft. of heating surface, with tubes $1\frac{5}{8}$ in. external diameter. The continuous running of this engine has enabled many useful observations to be made, among the most valuable being the test of durability of the fire-box with oil fuel. It has been suggested that with liquid fuel the distribution of heat cannot be so perfect as with a coal fire equally spread over the fire-grate, and that the operation of the steam jets of the burners would tend to shorten the life of the fire-box, unless protected by fire-brick walls. The reverse of both these suggestions has, however, been the outcome of the practical employment of oil fuel on the Great Eastern Railway locomotives, for whereas the average life of a copper fire-box in engines of precisely the same class and dimensions on similar duty has been but five-and-a-half years, the fire-box of engine 760 ran eight years and four months before renewal.

The position of the burners, arrangement of brick arch, blast pipe, etc., of the oil fuel tanks and pipes were also carefully watched and tested.

The experience gained was incorporated in the ten single-wheel bogie express engines designed by the author and built at Stratford Works in 1898, specially for running the fast sea-side expresses of the summer season. These engines are illustrated by a photographic reproduction (Fig. 2). The engines have

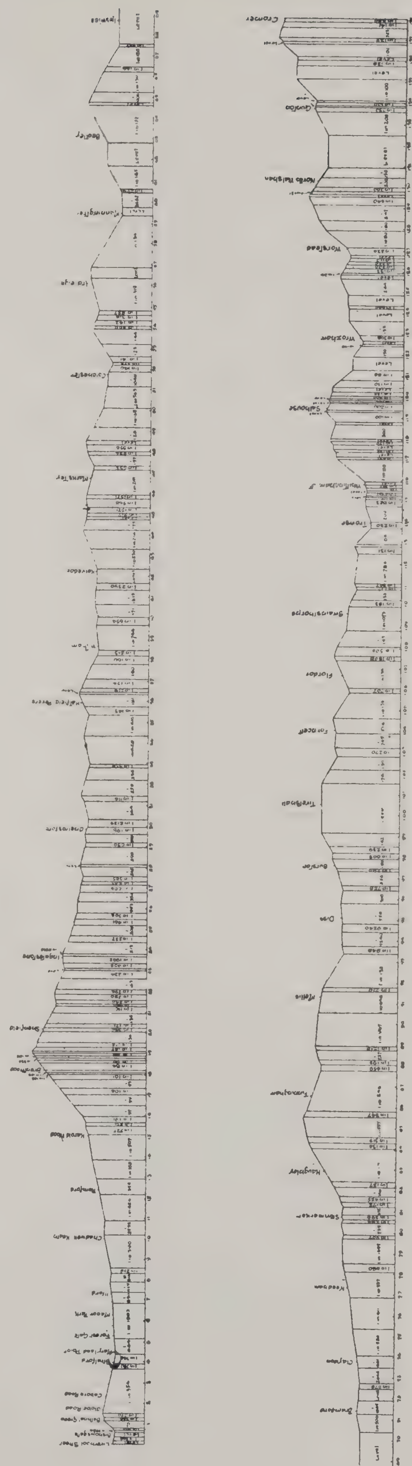


FIG. 3.—DIAGRAM OF GRADIENTS. LONDON (LIVERPOOL STREET) TO CROMER, VIÂ WENSUM CURVE.

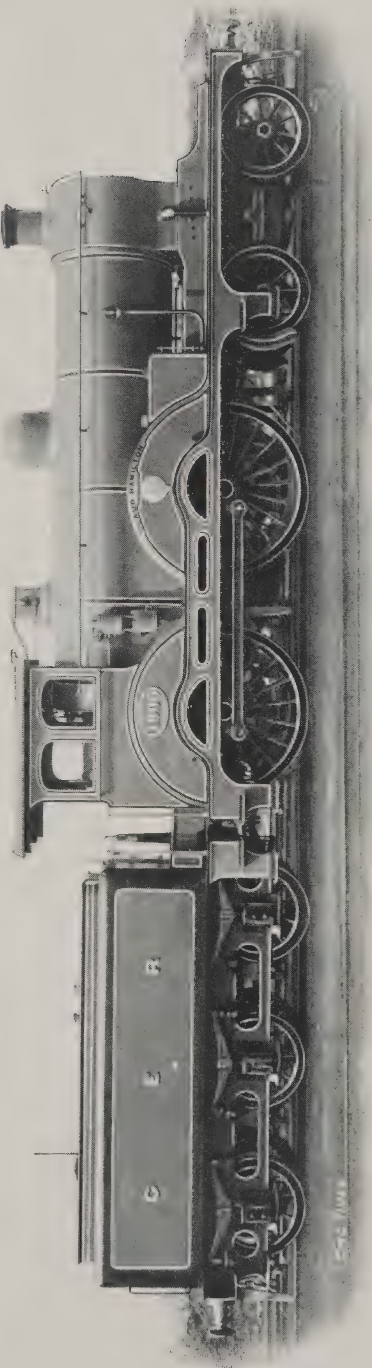


FIG. 4.—THE LATEST LIQUID FUEL ENGINE BUILT BY THE GREAT EASTERN RAILWAY.

cylinders 18 in. by 26 in., drivers 7 ft., and boilers with 160 lbs. working pressure, and fire-boxes with 20 sq. ft. of grate.

Engines of this type ran the fast Cromer express trains during the summers of 1898 and 1899, and did some remarkably good work in those periods. A diagram showing the grades of the line is appended. Engines of this class have repeatedly made the run of 138 miles on a consumption of 190 gallons of oil fuel, with which 6 cwt. of coal had been used to raise steam and keep an incandescent base on the fire-grate whilst standing. The time for the run under notice is 175 minutes. To cover the fire-grate, and form a porous layer through which air can percolate, for assisting the combustion of the oil fuel, old fire-brick broken into pieces of not more than 3 in. cube is used.

Increasing load necessitated more powerful engines than these mentioned, and early last year the author designed and built at the Stratford works eleven large, four-coupled, oil-burning express engines. One of these, the original of the photograph (Fig. 4), was sent to the late Paris Exhibition, where it received a *grand prix*. The chief dimensions are: cylinders, 19 in. by 26 in.; drivers, 7 ft. diameter; and bogie wheels, 3 ft. 9 in. diameter. The boiler contains 1,630·5 sq. ft. of heating surface, and has a grate of 21·3 sq. ft. area. The tender carries 715 gallons of oil fuel and 2,790 gallons of water. During the summer months these engines ran the Cromer express with trains, as shown in the diagram (Fig. 5), burning a mixture of creosote oil and gas tar as fuel.

The burners employed on these later engines are illustrated by Fig. 6, which shows the construction of the appliance. The connections for oil fuel and steam are marked. Briefly, the action of the burner is as follows: oil fuel delivered through the regulating valve is first admitted to the internal cones of

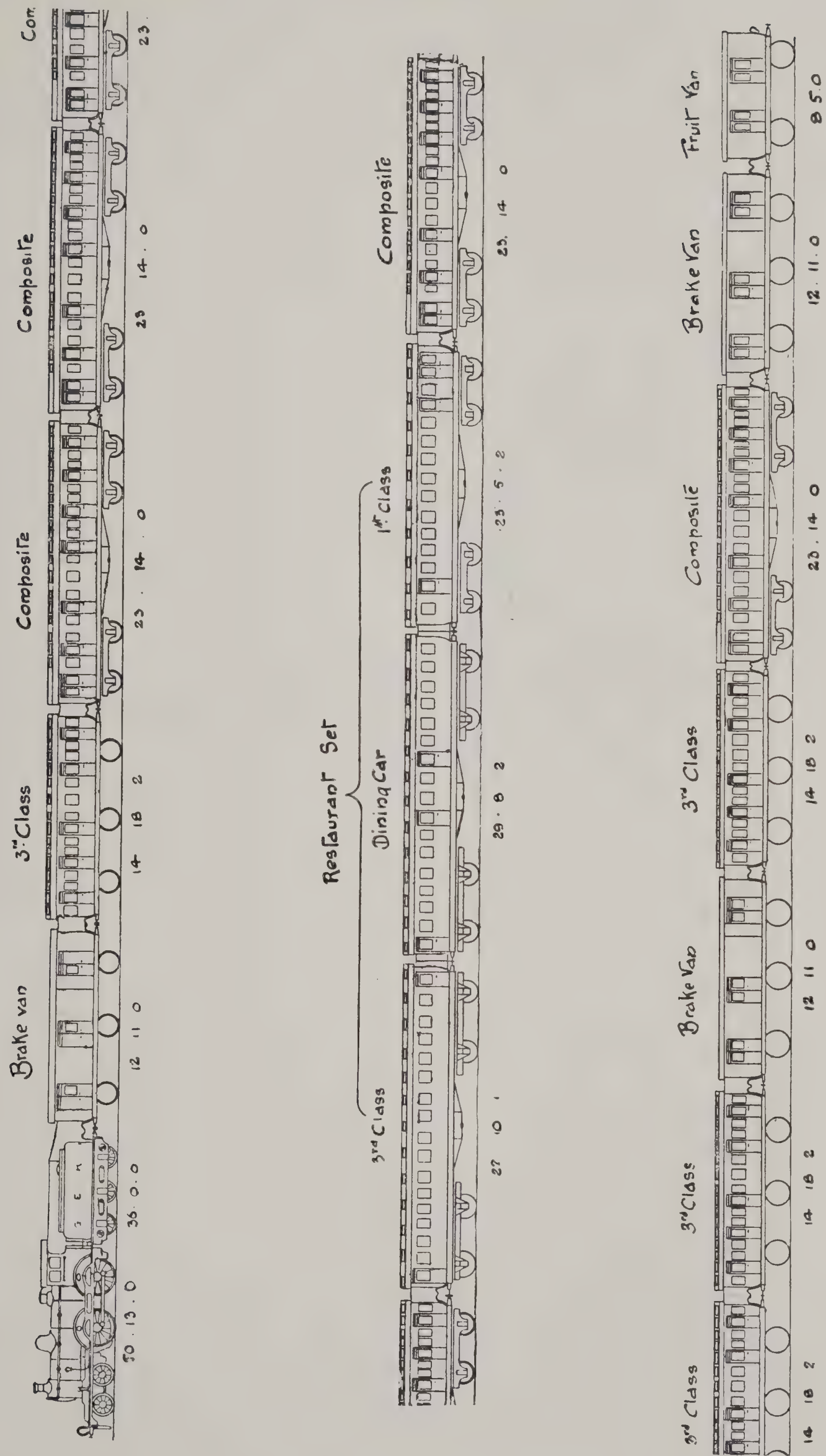


FIG. 5.—MAKE-UP OF LONDON—CROMER SPECIAL EXPRESS, 1900. TOTAL WEIGHT OF TRAIN EMPTY, EXCLUSIVE OF ENGINE AND TENDER 304 TONS 6 CWT., 1 QR.

the device, to be sprayed from the nozzle by steam supplied to the central annular jet. As this spray issues from the nozzle, a second portion of oil fuel is supplied through an outer channel, to fall over the first and be sprayed by it. To completely atomize and diffuse the sprays formed by the above-mentioned jets, a ring blower is provided, having fine steam jets issuing from its face diverted at such angles as to produce the maximum pulverizing effect with the minimum expenditure of steam. This latter item has been reduced on locomotives with the burners under notice to a fraction above 2 per cent. of the steam raised.

In the employment of liquid fuel a high temperature of the furnace is naturally a primary desideratum, and to assist in maintaining this on these engines (see Fig. 7), the different components of the oil fire are heated upon their way to the furnace by otherwise waste heat. The oil fuel is raised to a temperature corresponding very nearly to its ignition point by passage through a tubular heater, warmed by exhaust steam from the air-brake pump, whilst the steam taken from the highest point of the boiler dome is reheated as it comes in contact, in the cones of the burners, with hot air drawn through a series of heating-pipes arranged around the internal casing of the smoke-box.

The arrangements of tank and its connections are adopted from those that have been found most satisfactory in practice. The oil fuel is filtered, as it is filled into the tank, by passage through a gauze strainer having a fine mesh, which also acts as a precaution against any lights being incautiously introduced into the tank. From the reservoir the oil fuel is admitted through a large sluice valve to the exhaust steam-heating chamber, prior to its passage through the flexible hose-pipe to the controlling valves of the burners. The regulating gear for the oil fuel is of such a pattern that easy manipulation of the supply to

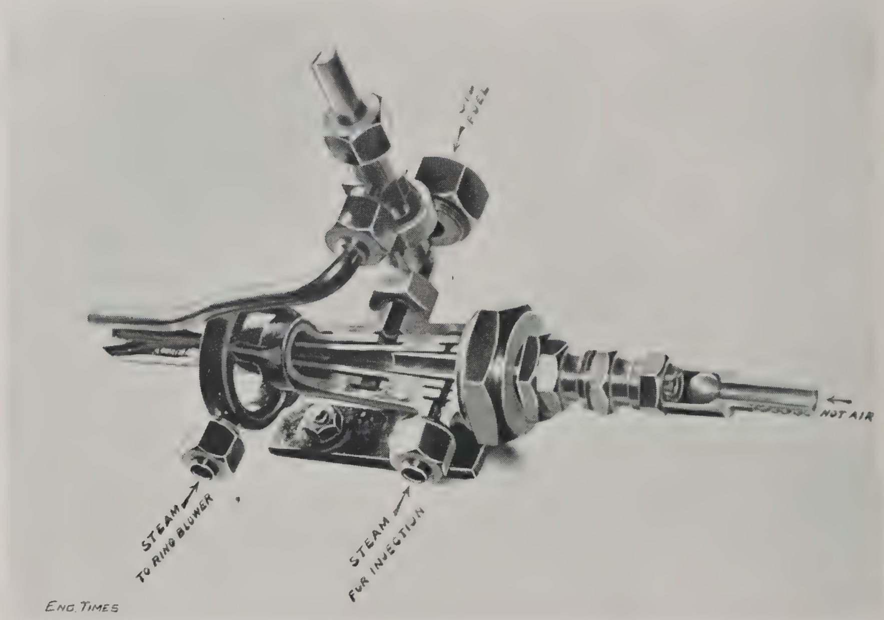


FIG. 6.—SECTIONAL VIEW OF LOCOMOTIVE PATTERN LIQUID FUEL INJECTOR. HOLDEN S PATENT, 1900.

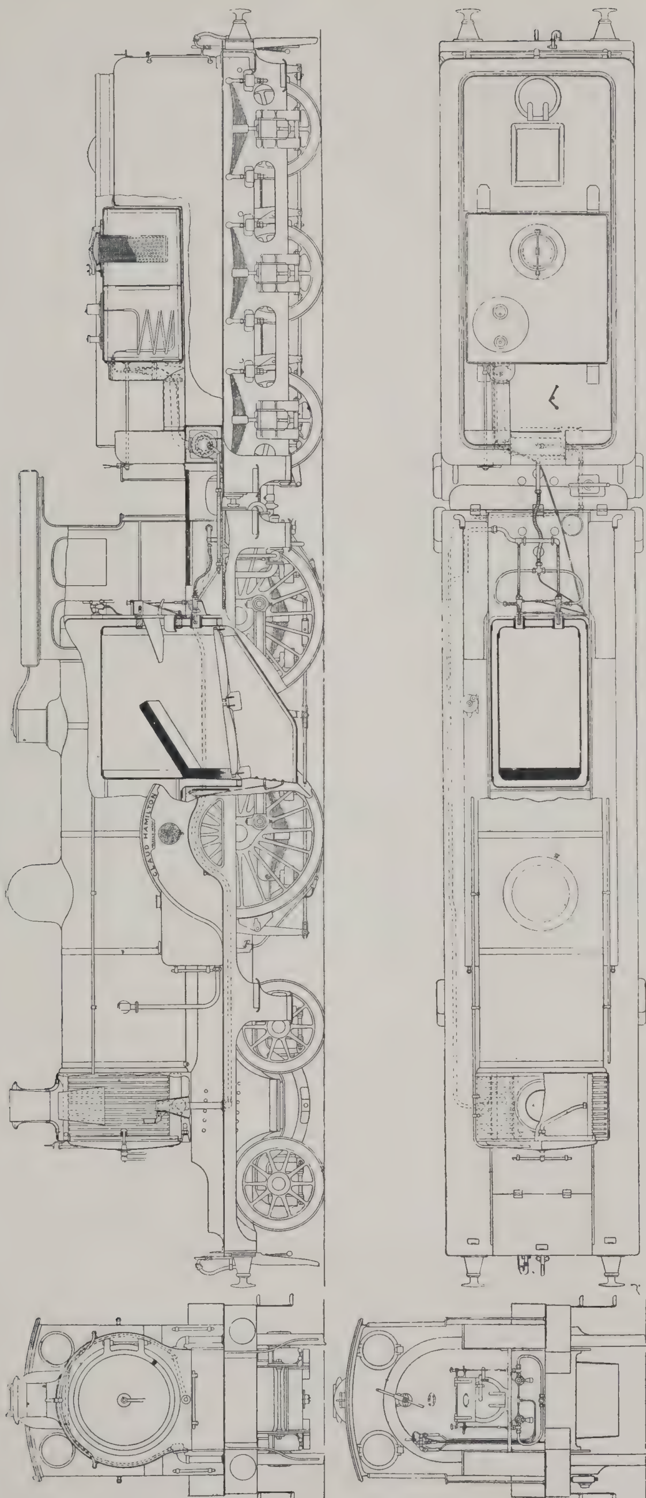


FIG. 7.—GREAT EASTERN RAILWAY 4-COUPLED BOGIE EXPRESS ENGINE FITTED TO BURN OIL FUEL. HOLDEN'S PATENT.

one or both of the burners is secured. The steam is controlled by a special fitting on the fire-box front, provided with packed cocks, grouped at a convenient point.

The method of storing and dealing with the oil fuel calls for some mention. The plant installed by the writer at the Stratford depôt illustrates in a striking manner the great advantages liquid fuel possesses over solid in portability and ease of manipulation. The fuel is untouched by manual labour from its arrival in tank waggons to its consumption on the locomotives; a total staff of four men, of whom one takes charge by night, is sufficient for the reception and distribution of all the oil fuel at present used on the Great Eastern Railway—approximately, 50,000 gallons per week. The photographs (Figs. 8 and 9) show the general scheme of the storage plant. On arrival, the tank waggons are emptied by gravity into a series of underground tanks situated in the rear of the small boiler shown on the right hand of the pictures, and immediately despatched for further consignments. The capacity of these low-level reservoirs is 50,000 gallons, and the contents are pumped by a steam rotary pump as required into the elevated cylindrical tanks (40,000 gallons) shown, which in turn feed the filling arms conveniently placed for charging the fuel tanks of the locomotives as they pass along the centre roads to the engine shed. As much of the work must necessarily be carried on by night, the storage and vicinity is illuminated by electric arc lights, whilst portable incandescent lamps with flexible connections hang from the arms for the convenience of the men filling the tanks. Sluice valves giving full opening areas and large pipes with easy bends have been adopted throughout.

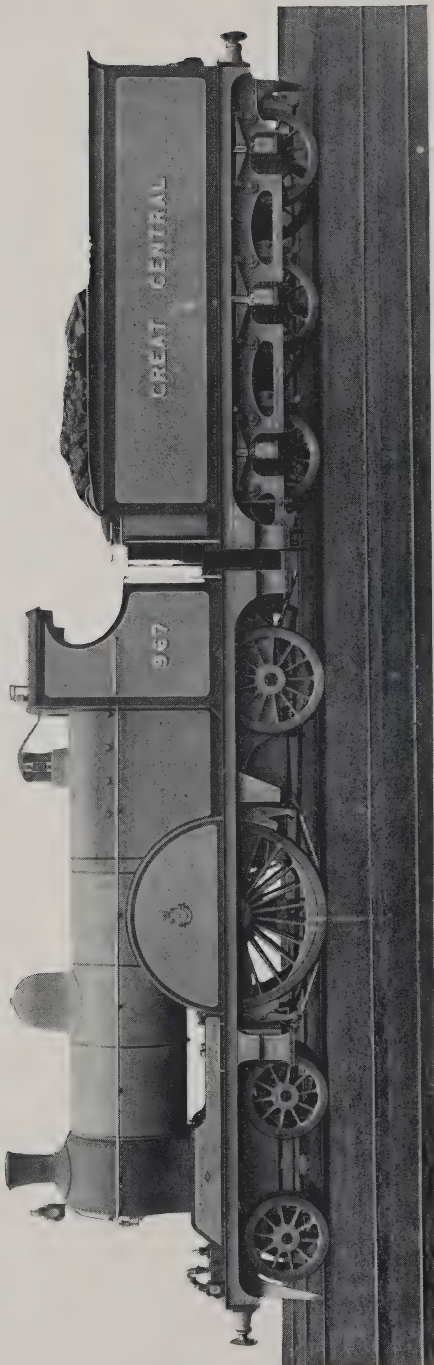
FIG. 8.—VIEW OF LIQUID FUEL STORAGE, SHOWING HIGH LEVEL TANKS, FILLING ARM, ETC.

As regards the advantages of the oil fuel on locomotives over the customary coal, its general adoption in so many countries where petroleum is plentiful,

FIG. 9.—VIEW OF LIQUID FUEL STORAGE, SHOWING AN ENGINE RECEIVING ITS SUPPLY.

and its use in many districts where close competition exists in price with wood and coal, is satisfactory evidence of its efficiency and desirability. On the long runs of fast trains, which are yearly increasing in number, one of the chief difficulties is the fire, which, being continuously urged for such long intervals, becomes choked with dirt and ashes. With oil-burning locomotives no such trouble exists, as the supply of fuel is regular, continuous, and entirely free from residue. An engine of the Great Eastern Railway (761) had, on a special occasion, to haul an express train from London (St. Pancras) to Scarboro' and back. The total distance covered was 532 miles, the engine being in steam some twenty-four hours. The fire was untouched during the whole time, and the engine steamed as freely during the last half-hour of the run as on its initial fifty miles of the journey.

Jas Holden

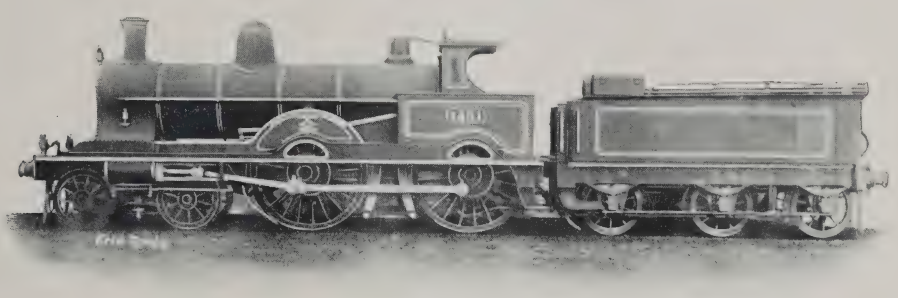


LATEST TYPE OF SINGLE-DRIVER EXPRESS ENGINE, GREAT CENTRAL RAILWAY. MR. HARRY POLLITT

MODERN BRITISH LOCOMOTIVE PRACTICE.

By CHARLES ROUS-MARTEN.

IT may possibly be unpopular to assert that the new century finds British locomotive practice in a transitional or tentative condition. Yet such is unquestionably the fact. British locomotive engineers are waking up by degrees to the recognition of the fact that while their engines are still unsurpassed in the whole world in certain respects—notably in swiftness, efficiency per unit of nominal power, perfection of workmanship, and durability of construction developments in British locomotive engineering would be utterly meaningless. For if the engines of the "nineties" were powerful enough, why do so large a proportion of our trains require two engines each, whereas trains of the some weight are readily hauled at equal speeds elsewhere by one engine per train? And why are almost all our locomotive engineers using boilers with 25 to 50 per cent. more capacity than was deemed needful a few years back?



LATEST TYPE OF EXPRESS ENGINE. LONDON AND NORTH WESTERN RAILWAY. FOUR-CYLINDER COMPOUND. MR. F. W. WEBB. (NO. 1501, NOW 1901.)

—these same engines nevertheless have fallen far short of what the rest of the world deems requisite in respect of haulage strength. They have also begun to realise that the shortage was due to deficient capacity in one single particular, that of boiler efficiency, but also in both of its dual phases—steam generation and steam pressure.

That this may be an unpopular statement I have already recognised. But I make it fearlessly for all that, and it is necessary to make it because else all that I have to say as to the latest If the former methods were adequate, the present prevalence of piloting and the various new departures are mere idle and wanton extravagance. If the new departures and so much "double-heading" are necessary, then the former engine dimensions were inadequate. There is no escape from this dilemma, and it constitutes the entire *raison d'être* of modern British locomotive engineering, as I am about to show.

For during the past decade the increase in the proportion of duplicated and piloted trains has been absolutely

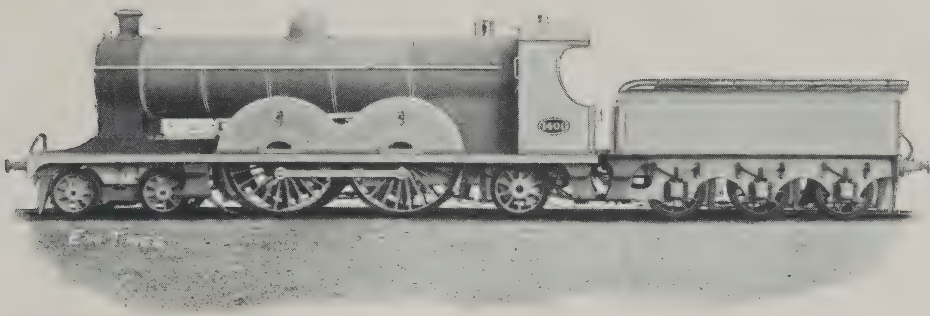
alarming in view of the costliness of these practices and their many drawbacks, including the double occupation of the road on the one hand, and the doubling of the *personnel* on the other. Consequently locomotive superintendents have been forced to look around them and see how it was that Britain alone among the countries of the world resorted to these expensive and unsatisfactory makeshifts, whereas other countries were able to act on the principle of "one engine one train." A feeble attempt was made to show that the difference was to be found in the superior weights of British train loads. This was promptly disposed of by a direct comparison of actual and not theoretical statistics, which showed that America and France were running, with one engine per train, heavier loads than those for which two engines were almost habitually used in Britain, and over gradients just as steep—sometimes steeper—and at speeds still higher. Every intelligent reader will of course understand that I am not comparing such exceptional gradients as those of Shap, Beattock, and Falahill in Britain, the Pyrenees in France, or the "Rockies," etc., in America, and that I am comparing actual definite work done under my own personal observation.

The solution of the problem promptly offered itself. While the majority of British locomotive engineers contented themselves with 900 to 1,200 sq. ft. of heating-surface, and 150 to 160 lb. per square inch steam-pressure for their express engines, Europe and America were employing 2,000 to 3,500 sq. ft. of heating-surface, and 200 to 230 lb. steam-pressure, with cylinder capacity and other dimensions proportionate, to say nothing of the wide development of the compound principle by which a specific volume of steam is made to do a large addition of practical work.

Awaking to these facts and reasons in the year 1899, largely through the indisputable proofs given of the superiority of foreign work, several leading British engineers proceeded with commendable energy to build locomotives with more boiler-power. Thus in place of 900 to 1,200 sq. ft. of heating-surface, most of the new engines of 1899–1901 have been given 1,500 to 2,050 sq. ft., and instead of being limited to 150 or 160 lb. per square inch of steam-pressure they generally have had 175, 180, or 200 lb. And this is by far the most important and valuable feature of modern British locomotive practice Even in its latest developments it falls short of the progress which has been made and is still being made on the European and American continents ; yet it is a valuable advance in the right direction. It is strange that the practice of compounding, which abroad is so rapidly moving forward toward what apparently promises to be universal adoption ere long, should still be so persistently disregarded in Britain. Mr. F. W. Webb, it is true, builds no other express engines than four-cylinder compounds, of which he already has brought out fifty since he introduced his "Jubilee" type in 1897, and most of his new goods engines are three-cylinder compounds. Also, it is a sort of "open secret" that an experimental compound is likely to be tried at Derby and another at St. Rollox. But there are as yet no signs of compounding elsewhere in Britain. Mr. Wilson Worsdell has not multiplied his one three-cylinder compound, and there have been no revivals of the experiments with tandem compounds which were tried some years ago on the Great Western and North British lines. In Europe, however, more than a thousand compound locomotives have been built on Monsieur A. de Glehn's four-cylinder compound system, beside numbers of the Mallet and Von Borries

EXPRESS PASSENGER LOCOMOTIVE for the DUTCH RAILWAYS.

Built by Messrs. Sharp, Stewart & Co., Glasgow.

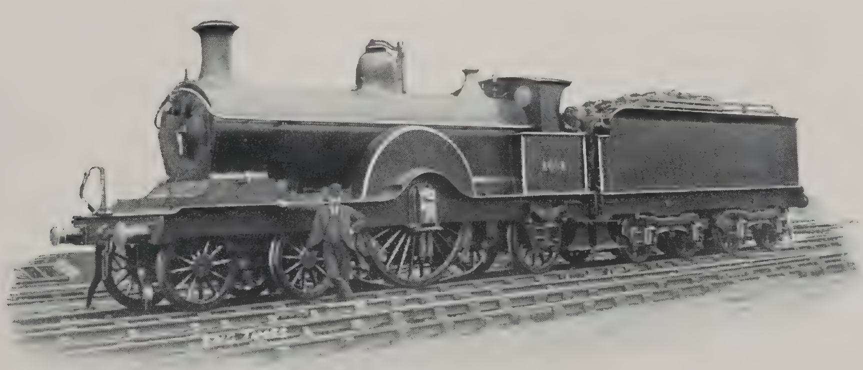


LATEST TYPE OF EXPRESS LOCOMOTIVE FOR THE LANCASHIRE AND YORKSHIRE RAILWAY.
MR. J. A. F. ASPINALL.

two-cylinder types, and in America the Vauclain four-cylinder compound system appears to be making steady headway.

Yet manifestly the general adoption of compounding in this country is only a question of time. Augmented power is the crying need of the day, so that needless duplication and "double-heading" may be avoided. But the restrictions of the British loading-gauge impose severe limitations to lateral or vertical extension of present locomotive dimensions. Mr. J. A. F. Aspinall, with his Lancashire and Yorkshire engine, No. 1400, closely approached this limitation, although undoubtedly he could increase the tractive force by reducing the diameter of his driving-wheels, now 7 ft. 3 in. Still there are and must be limitations of boiler magnitude, and so the necessity arises of utilising to the utmost advantage the boiler-power that is available. This is done by the compounds, because they can use steam at a higher pressure without waste, as they employ the same steam a second time, though at a lower pressure. Thus the general neglect of compounding seems to me one of the most striking, and I may add strange, features of modern locomotive practice in Britain.

Coming next to more detailed points of modern British practice, I am inclined to place prominently among these the growing tendency toward the extinction of the single-wheeler type. It is true that a few of this class have



LATEST TYPE OF SINGLE-WHEELER EXPRESS ENGINE. MIDLAND RAILWAY. MR. S. W. JOHNSON.

recently been built for the Midland and Great Central lines, but virtually in completion of orders of much earlier date. Also two of this class have been built on the Great Northern during the past three years. But these bear a very small, almost microscopic, proportion to the number of coupled express engines constructed during the same period, and the chief mechanical engineers of two British railways, hitherto strong exponents of the single-driver type—the Great Western and Great Eastern—have distinctly expressed their intention to build only Great Northern and all old ones rebuilt have been domed ever since Mr. Ivatt's advent. With Mr. H. S. Wainwright's accession to the South Eastern and Chatham chieftaincy came also the dome and went the perforated pipe. This meant universality in the use of the dome, England having long been the only country to dispense with it even occasionally. But then quite unexpectedly Mr. W. Dean brought out at Swindon a new Great Western express type, with a boiler so large and pitched so high as to leave no room for a dome, and this has been followed by

NEWEST TYPE OF EXPRESS ENGINE. GREAT NORTHERN RAILWAY. "990" OR "ATLANTIC" CLASS. MR. H. A. IVATT.

coupled engines henceforward, as being able to do all that the single-wheelers can do, while capable of much that the single-wheelers cannot do, and more trustworthy generally with heavy fast trains.

With the retirement of Mr. J. Stirling from the locomotive superintendency of the South Eastern Railway it appeared as if the domeless engine, taking its steam from a perforated pipe, would also pass into total disuse. It had long vanished from the Great Eastern; longer still from the London and South Western; more recently from the Great Western; while all new engines on the the construction of a large number—fifty or more, I believe—of domeless express locomotives, as well as two domeless goods engines. In fact, all the engines built for the Great Western in 1900, or now in course of construction, are without domes.

Another revival so far peculiar to the Great Western has been that of outside bearings and cranks to the coupled wheels. This plan, too, had seemed on the verge of disappearance, even on the Great Western, a few years ago, when several types of four-coupled and six-coupled engines, as well as tank engines, came out with inside bearings

FOUR-CYLINDER NON-COMPOUND EXPRESS ENGINE. GLASGOW AND SOUTH WESTERN RAILWAY.
MR. J. MANSON.

only. But now all new Great Western locomotives have the outside arrangement once more.

Perhaps one of the most prominent characteristics of modern British locomotive practice is the persistent adherence to the inside position for the cylinders. At one time inside cylinders were practically unknown on the Caledonian Railway, and also, save in the case of goods engines, on the London and South Western and Great Eastern lines. But now outside cylinders are not seen on any of those railways, save as survivals of an obsolete past. It is curious that the most famous modern engines with outside cylinders, the late Mr. Patrick Stirling's 8 ft. single-wheelers, had the cylinders in that position only because they could not be got inside without certain disadvantages, Mr. Stirling being a strong opponent of the outside position. The case is exactly the same at the present day with reference to the new six-coupled express engines of Mr. W. Worsdell and Mr. P. Drummond, as also to Mr. H. A. Ivatt's "990" or "Atlantic" type, to the four-cylinder engines of Mr. D. Drummond and Mr. J. Manson, and to Mr. F. W. Webb's compounds. All of these eminent engineers place their cylinders outside merely because they cannot devise any satisfactory way of getting them *inside* the frames. Thus all British outside cylinder engines are so under protest as it were. This is the more curious, inasmuch as on the European continent, except in Holland and Belgium, the case is exactly reversed, the inside cylinder position being, as a rule, only resorted to when absolutely unavoidable, as in the case of the four-cylinder

FOUR-CYLINDER NON-COMPOUND EXPRESS ENGINE. LONDON AND SOUTH WESTERN RAILWAY.
MR. D. DRUMMOND.

compounds; while in America I believe inside cylinders are almost if not wholly unknown. Here again British practice reverses that of the rest of the world.

In favour of outside cylinders it is urged, with undoubted justice, that superior accessibility of the working parts is thus secured, they being more easily inspected and more readily got at for repairs. It is also contended that the absence of the cranked axle is an advantage, owing to its inherent weakness of form as a girder or column, as compared with the straight axle of outside cylinder engines. On the other hand, it is maintained on behalf of inside cylinders that they are less exposed to variation of atmospheric temperature, consequently are less liable to be chilled, with the result of condensation; that the inside position gives an easier and more direct motion in the middle line of movement, as compared with the alternate "boxing" action of outside cylinders; that the working parts are less exposed to dust and dirt and to changes of temperature, and that the theoretical weakness of the crank axle has been practically eliminated through improved methods of construction, while it is free from one drawback held to attach to the straight axle with outside cylinders, namely, that the straight axle, being driven from each extremity, is subject to torsional stress, analogous to the alternate twisting and untwisting of a rope, before motion is set up, it being argued that this must have a detrimental effect in some degree upon any fibrous structure.

After many years' careful observation on this head, I am forced to the conclusion that while each method possesses the merits claimed for it by its advocates, it has *not* in actual practice the drawbacks predicated of it theoretically by its opponents. No disadvantage is found to attach to the use of outside cylinders in the six-coupled engines of Mr. Worsdell and Mr. P. Drummond; or in Mr. Ivatt's "Atlantic" type, or Mr. Webb's compounds, or Mr. Stirling's 8 ft. single-wheelers; or to inside cylinders when used on the European Continent in the four-cylinder compounds. It may, in fact, be fairly said that with modern excellence of construction one of the plans is for practical purposes as good as the other. And so I do not anticipate that British engineers will be easily dispossessed of their preference for inside cylinders any more than will Continental and American engineers of their liking for the outside position.

Modern locomotive practice recognises the marked superiority of the results obtained in the way of steam generation from direct contact between the water receptacle and the flames of the fire, as compared with those given by mere extension of tube area. Indeed, the increased heating-surface obtained through mere lengthening of the tubes is as a rule of little practical value. Thus the Serve form of tubes, which by means of internal ribs, or "fins," gives enhanced heating capacity while the tube-length is reduced, has come much into favour in Europe, and is occasionally used in England. But the ideal of modern designers is to get the largest and most efficient fire-box possible. And so the newest fire-boxes are either of the Belpaire type—which, by the way, is being abandoned in Belgium, the country of its origin—or else greatly lengthened or fitted with water tubes which convey water from the boiler, pass through the fire-box, and then return the heated water to the boiler, thus most valuably enhancing the rapidity of steam generation. This plan has been brought to a high degree of efficiency by Mr. D. Drummond, who uses it in all his new London and South Western engines with excellent results. It will probably come into much wider use as its value is appreciated.

Extended smoke-boxes have come a good deal into vogue of late, notably on the Great Western. They possess several advantages. For one thing, they cause a far better clearance of the tubes from ashes and *débris*, and thus facilitate steam production. Secondly, they have proved very useful in preventing, or at least checking, the emission of sparks and fragments of incandescent fuel, especially when a horizontal "grid" is placed above the tube ends but clear of the blast pipe, or when a loose bag of chainwork, like chain-mail, is suspended below the chimney. The prevention of spark saved dead weight. That is to say, the tenders used on the West Coast Anglo-Scottish expresses weigh 25 tons on the London and North Western from London to Carlisle, and 45 tons on the Caledonian thence. However, the system has been adopted in comparatively recent days by the Great Western, Great Eastern and North Eastern, is in process of introduction by the Great Northern, and is about to cross the Channel to become acclimatised on the French Northern line. Its universal adoption in this country seems certain to be only a matter of time.

LATEST TYPE OF EXPRESS ENGINE. LONDON, BRIGHTON AND SOUTH COAST RAILWAY. "SIRDAR" CLASS.
MR. R. J. BILLINTON.

emission has long been an important desideratum in view of the damage often caused by fire to cornfields, ricks and woods.

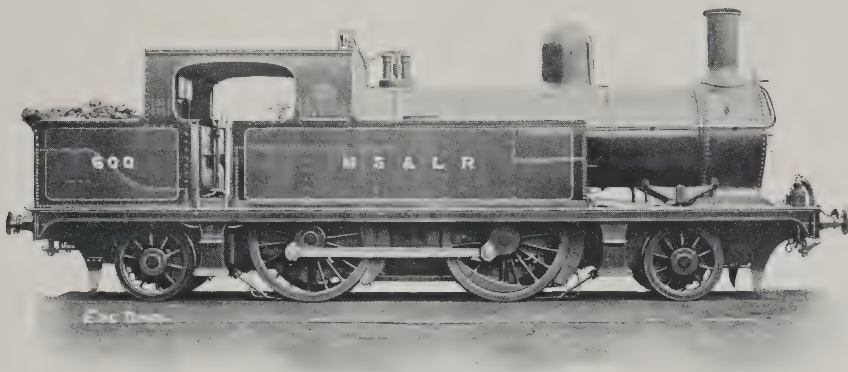
The use of the road trough and tender water scoop has steadily gained vogue, although with astonishing slowness. Seeing that this most beneficial appliance was invented by Mr. John Ramsbottom nearly forty years ago, it is surprising that it should only have been adopted during the past two or three years by any other line than the London and North Western, except during the past decade or so by the Lancashire and Yorkshire, especially as one result has been to diminish the necessary weight of tenders by some 20 tons all

Tenders mounted on two four-wheel bogies are steadily coming into fashion in Britain. They have long been universal in America, and it is probable that even when the adoption of the trough and water-scoop reduces the tender-weight by fifteen or twenty tons, the superiority and adaptableness of bogie-tenders to road curves will cause them, once tried, to become permanent institutions.

Such, then, are the chief and prevalent characteristics of modern locomotive practice in Great Britain. But it may be interesting to glance in conclusion at the specific methods most recently adopted by each of the principal railways of this country, taking them in

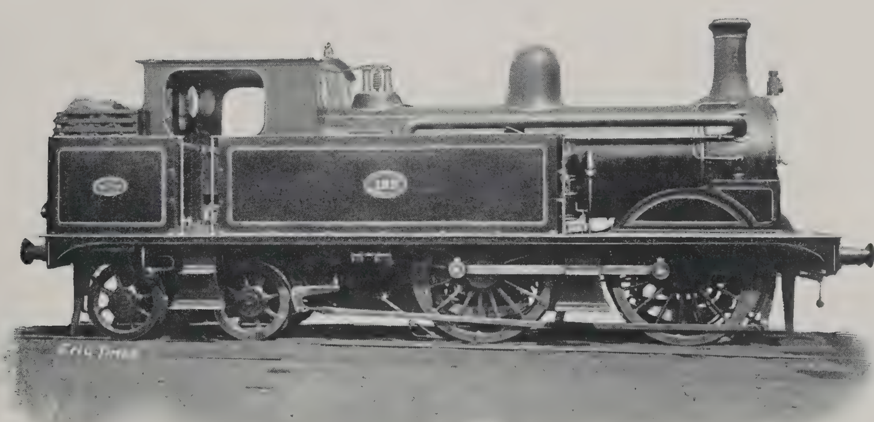
"Bradshaw's Guide" order, a more convenient mode than the alphabetical.

For the Great Western, Mr. W. Dean builds express engines with four 6 ft. 8 in. wheels coupled ("Atbara" class) for general duty, and with 5 ft. 8 in. wheels ("Camel" class) for specially severe gradients and for heavy stopping trains. Each class has inside cylinders 18 by 26, large, high-pitched, domeless boilers with 1,630 sq. ft. of heating surface and 180 lb. steam-pressure. Mr. Dean's latest goods engine has similar boiler, but 4 ft. 8 in. wheels, six-coupled. All three classes have outside bearings and cranks and leading four-wheeled bogies. For the London and South Western, Mr. D. Drummond has recently built a large number of express engines ("702" class) with 6 ft. 6 in. coupled wheels, cylinders 18½ by 26, 1,500 sq. ft. of heating surface (including that supplied by water-tubes in fire-box) and 175 lb. steam-pressure. Mr. Drummond's one four-cylinder non-compound engine, built several years ago as an experiment, has not so far been perpetuated, but I hear that more are to be built. On the London, Brighton, and South Coast line Mr. R. J. Billinton has placed three new express locomotives, which are virtually enlargements of his "Bessemer" type. The new engines, "Sirdar" class, have 6 ft. 9 in. wheels coupled, inside cylinders 19 by 26, 1,600 sq. ft. of heating surface, and 180 lb. steam-pressure. Mr. H. S. Wainwright has designed for the South Eastern and Chatham a new express type, with inside cylinders 19 by 26 and 6 ft. 8 in. coupled wheels, which have begun running during the current spring. Mr. J. Holden's latest express type on the Great Eastern is his liquid-fuel-burning Paris Exhibition engine, "Claud Hamilton," which has 7 ft. coupled wheels, inside cylinders 19 by 26, 1,600 sq. ft. of heating surface, and 180 lb. steam-pressure. For the Great Northern, Mr. H. A. Ivatt has built since his accession to office no fewer than 100 engines with four-coupled 6 ft. 6 in. wheels, inside cylinders 17½ by 26, and leading bogies, forty of these differing from the rest in having larger boilers, but the entire class involving no specially novel departure. But Mr. Ivatt has also brought out a type quite new to Britain, that known as the "Atlantic" in America, and the "990" on the Great Northern, viz., with leading four-wheeled bogie, four-coupled driving-wheels under the middle of the boiler-length, and a pair of trailing wheels. Eleven of these have been placed on Great Northern metals: they have 6 ft. 6 in. coupled wheels and outside cylinders 19 by 24, 1,442 sq. ft. of heating surface, and 175 lb. steam-pressure. Mr. F. W. Webb has continued to built his four-cylinder compound express engines of the "Jubilee" class, with 15 by 24 high-pressure cylinders outside, 20½ by 24 low-pressure cylinders inside, all driving the front pair of 7 ft. coupled wheels, 1,379 sq. ft. of heating surface, 200 lb. steam-pressure. For the Midland, Mr. S. W. Johnson has completed another batch of his 7 ft. 9 in. single-wheelers: cylinders 19½ by 26, 1,217 sq. ft. of heating surface, 180 lb. steam-pressure. These have double-bogie tenders. A new class of 6 ft. 9 in. four-coupled express engine is under construction at Derby. Two important new types of express engines have come out recently on the North Eastern Railway, designed by Mr. Wilson Worsdell. Those of the "2001" class have leading four-wheel bogies, six-coupled 6 ft. wheels, outside cylinders 20 by 26, 1,769 sq. ft. of heating surface, 200 lb. steam-pressure. A more recent variant of this type, with 6 ft. 8 in wheels six-coupled, is now in course of construction at Gateshead. The second new North Eastern type has four-coupled wheels 6 ft. 9 in. in



ONE OF TWO STANDARD TYPES OF BRITISH TANK ENGINES. GREAT CENTRAL RAILWAY.
MR. H. POLLITT.

STANDARD TYPE OF BRITISH GOODS ENGINE. CALEDONIAN RAILWAY. MR. J. F. M'INTOSH.



ONE OF TWO STANDARD TYPES OF BRITISH TANK ENGINES. SOUTH EASTERN AND CHATHAM RAILWAY.
MR. W. KIRTLEY.

diameter, inside cylinders 19 by 26, 1,527 sq. ft. of heating surface, and 200 lb. steam-pressure. Just before his retirement from the locomotive superintendency of the Great Central Railway Mr. Harry Pollitt brought out the first of a new class of 7 ft. 9 in. single-wheelers, with cylinders 19½ by 26, and leading bogie, five more having been completed by his successor, Mr. Robinson. But the majority of the Great Central engines built by Mr. Pollitt have 7 ft. coupled wheels, 18½ by 26 cylinders. These are very numerous. Mr. J. A. F. Aspinall, just before his acceptance of the Lancashire and Yorkshire general managership, designed and built forty very large ten-wheeled express engines, which still remain the standard type on that line. They are known as the "1400" class, and have 7 ft. 3 in. coupled wheels, cylinders 19 by 26, 2,052 sq. ft. of heating surface, Belpaire firebox, 175 lb. steam-pressure, leading four-wheel bogie, and a pair of trailing wheels. The latest North British type built by Mr. M. Holmes has 6 ft. 6 in. coupled wheels, cylinders 18¼ by 26, 1,350 sq. ft. of heating surface, 175 lb. steam-pressure. Mr. J. Manson designed and built for the Glasgow and South Western several years ago a new type of four-cylinder non-compound express engine, with 6 ft. 9 in. coupled wheels, inside cylinders 14½ by 26, outside cylinders 12½ by 24, and 165 lb. steam-pressure. It has not yet been multiplied. For the Caledonian Railway, Mr. J. F. M'Intosh has lately brought out a third enlarged version of his well-known "Dunalastair" type, which came out early in 1896, and which had 6 ft. 6 in. coupled wheels, inside cylinders 18¼ by 26, 1,400 sq. ft. of heating surface, and 160 lb. steam-pressure. The second version, known as "Breadalbane" class, were given 19 in. cylinders, 1,500 sq. ft. of heating surface, and 175 lb. steam-pressure. The third and latest "900" class have 1,600 sq. ft. of heating surface and 180 lb. steam-pressure. Mr. P. Drummond has put two new classes of express locomotives recently on the Highland line. One closely resembles his brother's London and South Western "702" class, but has 6 ft. coupled wheels, and cylinders 18¼ by 26. The other resembles the North Eastern "2001" class, but has larger boiler, with 2,050 sq. ft. of heating surface, 5 ft. 9 in. driving wheels, six-coupled, outside cylinders 19½ by 26, 200 lb. steam-pressure, four-wheeled leading bogie.

These are the latest types of express engines on the leading railways of Britain. That is to say, it is these engines that are being most recently built for modern main-line passenger work in all its phases. For urban and suburban and branch-line duty, tank engines are used. These as a rule have the leading and driving wheels coupled, usually 5 ft. 6 in. in diameter, with a trailing four-wheeled bogie. Some have the second and third pairs of wheels coupled, with radial axles to the leading and trailing wheels. A few have six 4 ft. wheels all coupled, as on the London, Brighton and South Coast, and Great Eastern. Still fewer have six wheels coupled with a pair of radial trailing wheels, as on the London and North Western, London, Brighton and South Coast, and Lancashire and Yorkshire. Goods engines, as a rule, are much as they were in years gone by, differing chiefly in having larger boilers and cylinders. They generally have six wheels all coupled, and with a diameter of either 5 ft. or an inch or two more or less, with cylinder 17 to 18½ in., and piston stroke 24 to 26 in. Many on the London and North Western have eight-coupled wheels, and are built on Mr. F. W. Webb's three-cylinder compound system, with two outside cylinders 15 by 24, and one inside low-pressure cylinder 30 by 24.

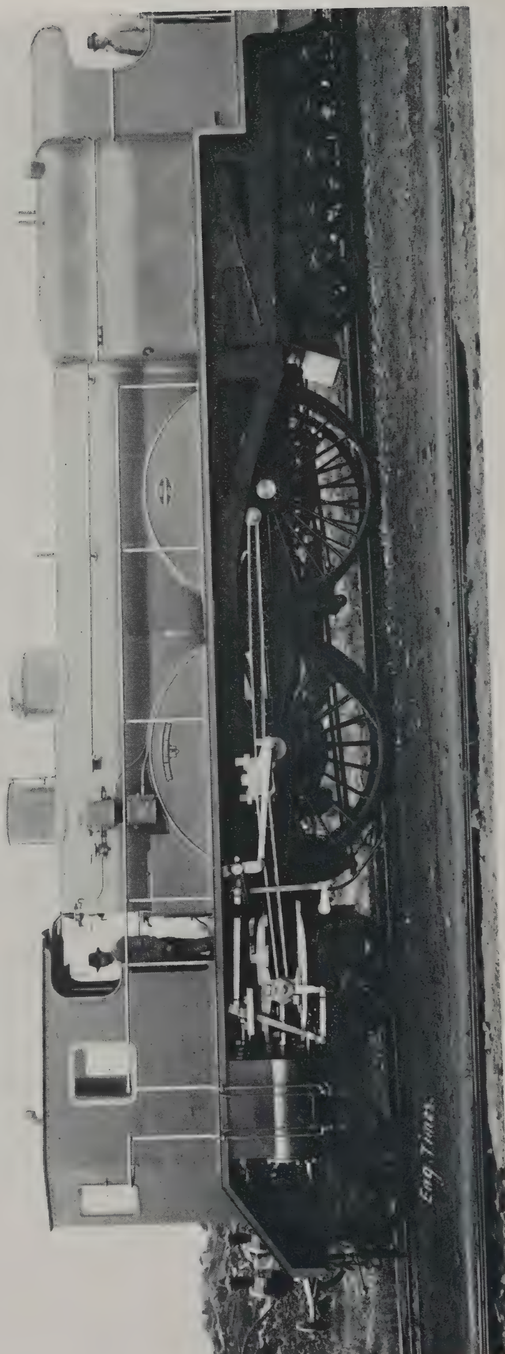
PASSENGER LOCOMOTIVE for the LONDON & SOUTH WESTERN RAILWAY.

Built to the designs of Mr. D. Drummond, Locomotive Superintendent, by Messrs. Dubs & Co., Glasgow Locomotive Works, Glasgow.

Some eight-coupled goods engines have also been built at Horwich for the Lancashire and Yorkshire, with vast boilers and cylinders similar to those of the "1400" class of passenger locomotives. It is understood that eight-coupled goods engines are also to be used on the Great Northern and some other lines. They have been employed for many years with success on American and European railways.

The illustrations in this article are reproductions of photographs by Mr. F. Moore, Charing Cross Road, London.

C. Rous-Marten



14-WHEEL EXPRESS PASSENGER LOCOMOTIVE (THUILE SYSTEM).

Built by Messrs. Schneider & Co., Creusot.

LOCOMOTIVES IN FRANCE.

By Prof. ED. SAUVAGE.

LONG and careful investigations would be necessary to get a complete knowledge of the locomotives used in France, owing to the great variety of designs made at different times for the several railway companies, specially as old engines are still found in service. However, a great improvement in the way of uniformity is noticeable, and the latest types of locomotives on the various lines look more like members of the same family. Of course, these latest types are the more interesting to study; but the mention of some older locomotives, still doing good service in large numbers, ought not to be omitted.

The following pages will first mention the more important types of the preceding period, which continue running on the French railways. Nearly all these types were designed before 1890, and even 1880. Next will come the description of the modern French locomotives, and, thirdly, of different details in their construction which seem specially interesting.

With the exception of the old Crampton engines, which long ago ceased to make any service of importance, single wheelers have never met with great favour in France (putting aside the very first locomotives in the infancy of the railways).

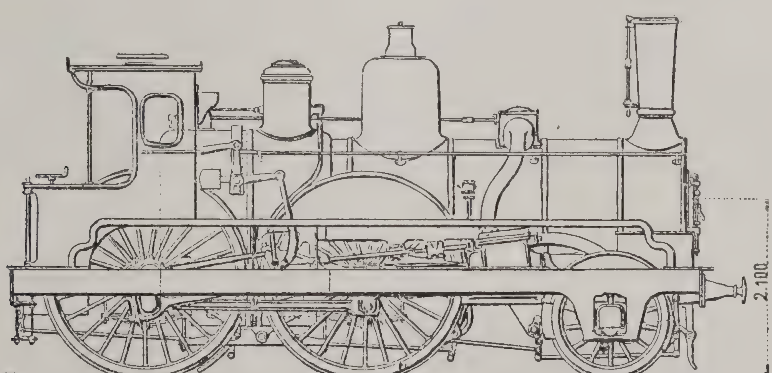


FIG. 1.—EXPRESS LOCOMOTIVE OF THE EST RAILWAY (ORDERED, WITH SOME ALTERATIONS, FROM 1878 TO 1889).

Grate area, 18·6 *to* 29·6 *sq. ft.* *Stroke of Pistons*, 24 *and* $29\frac{1}{4}$ *in.* *Diameter of Cylinders*, 17 *and* $17\frac{5}{16}$ *in.* *Weight in running order*, 41·9 *to* 46·5 *tons.*

Among the express engines with two coupled axles may be mentioned the locomotive of the Est Railway, with outside cylinders driving the rear axle (Fig. 1). The Nord used locomotives with inside cylinders and outside frames, somewhat similar to engines designed by Mr. Sturrock for the Great Northern Railway, but with an increased grate, which extended partly over the rear

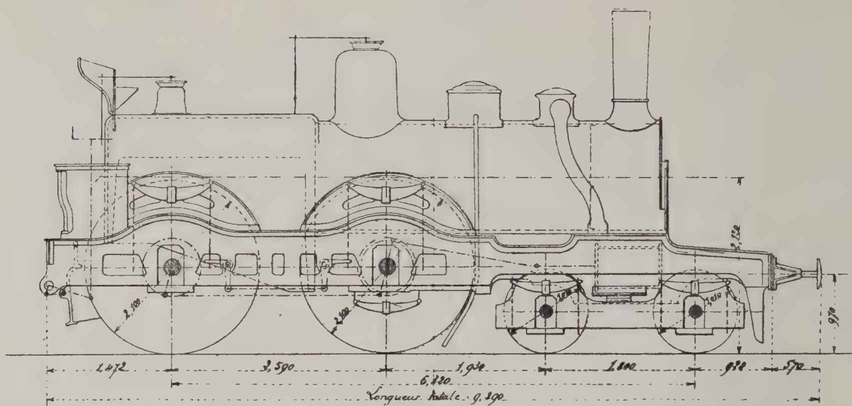


FIG. 2.—BOGIE EXPRESS LOCOMOTIVE OF THE NORD RAILWAY (FIRST ORDERED IN 1877).

Grate area, 25 sq. ft. *Stroke of Pistons, 24 in.* *Diameter of Cylinders, 17 to 17⅝ in.*
Weight in running order, 42 tons.

axle. In 1877, a bogie was used in place of the leading axle (Fig. 2); these were very good engines for the time. A little later the Ouest produced an express engine, the bogie of which had a lateral play, and somewhat similar to the Midland Railway engine.

On the P. O. and P. L. M. Railways, express locomotives, with two coupled axles between two carrying axles and with outside cylinders (Fig. 3), were largely used. It is worthy of remark that this type of engine, although not very commendable in itself, made an excellent service at high speeds on the P. O. On the P. L. M. these engines were renowned rather for power than for speed. Some of these have been recently rebuilt with a bogie in front.

A special mention must be made of the powerful locomotive built by the Est in 1890, conspicuous for its "Flaman" boiler with two barrels (Fig. 4). Although the complication of this boiler may be criticised, this construction marks a step in the right direction, a great increase in the power of passenger locomotives designed for high speeds.

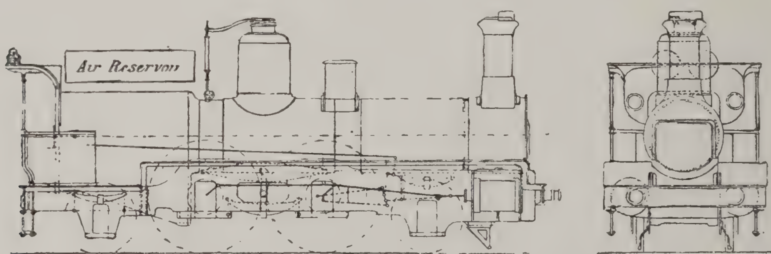


FIG. 3.—LOCOMOTIVE OF THE P. L. M. RAILWAY (FIRST ORDERED IN 1876).

Grate area, 23 sq. ft. *Stroke of Pistons, 25½ in.* *Diameter of Cylinders, 19⅝ in.*
Weight in running order, 47 tons.

For ordinary passenger trains a large variety of locomotives of moderate size have been and are still used, with three axles, of which two or all are coupled. Until recently, the goods service was chiefly made by locomotives with three or four axles, all coupled. The three-coupled engine, with outside cylinders, was extensively used, specially on the P. L. M. Railway. In addition to

these locomotives this system used, since 1881, a more powerful engine, with three coupled axles and a carrying axle under the firebox. Other railways used three-coupled engines with inside cylinders. On the Nord, and on the Est, and on the steep grades of the P. L. M. and P. O. Railways, four-coupled engines, with small wheels, were preferred. Some of these engines (Fig. 5) made and still make very good service for hauling heavy trains, specially on the Nord, but in many cases these sq. cm. (199 to 228 lb. per sq. in.). These are compounds with four cylinders: two high-pressure cylinders placed outside drive one axle, and two inside low-pressure cylinders are connected with another axle. Coupling rods are used. The advantages of preserving the coupling, which does not appear as absolutely necessary, have been discussed at some length in THE ENGINEERING TIMES (see "Notes on English and French Compound Locomotives," Dec., 1900); by their use the two pistons on

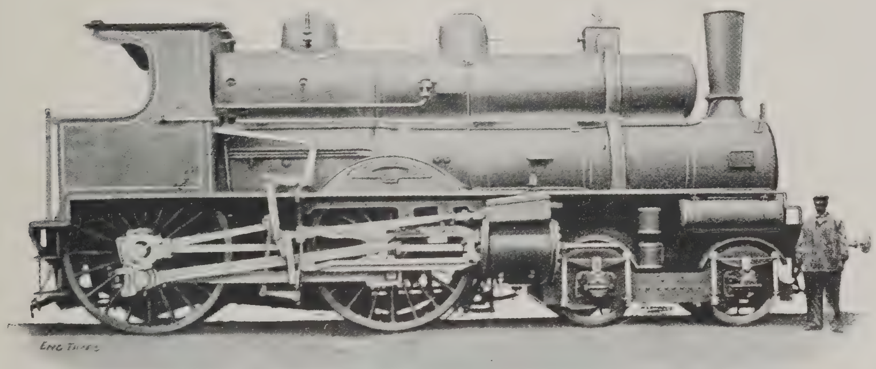


FIG. 4.—EXPRESS LOCOMOTIVE OF THE EST RAILWAY WITH "FLAMAN" BOILER (FIRST ORDERED IN 1890.

Grate area, $23\frac{1}{8}$ *sq. ft.* *Heating surface*, $1811\frac{1}{2}$ *sq. ft.* *Boiler pressure*, 171 *lb. per square inch.*
Diameter of Cylinders, $18\frac{1}{2}$ *in.* ($19\frac{11}{16}$ *in. on the first engines*). *Stroke of Pistons*, $26\frac{1}{16}$ *in.*
Diameter of Driving Wheels, 6 *ft.* $10\frac{5}{16}$ *in.* *Weight in running order*, 55·87 *tons.* *Adhesive weight*, 32·87 *tons.*

engines are too slow for the present requirements.

Amongst the types of tank engines may be mentioned the compact three-coupled locomotive of the Ouest (Fig. 6), and the powerful locomotive of the Est, with three coupled axles and a carrying axle under the firebox. Several of these engines have been recently rebuilt with a bogie in front and three coupled axles.

Recent French locomotives are conspicuous for their large boilers, carrying on a high pressure of steam. The grate area is about 2·5 sq. m. (27 sq. ft.), and in some cases larger; the effective pressure is 14, 15, and even 16 kg. per each side of the locomotive may be set with cranks at 180°, so as to have always opposite movements, and in this way the disturbing forces due to their motion are largely reduced. In some cases another disposition of the cranks has been adopted: they are not directly opposite, but set with an angle of about 162°. The object is to get a more uniform pull during a revolution of the wheels, which is advantageous specially when starting; but the first disposition was generally preferred in the latter designs.

Speaking of compound locomotives, it must not be forgotten that engines of

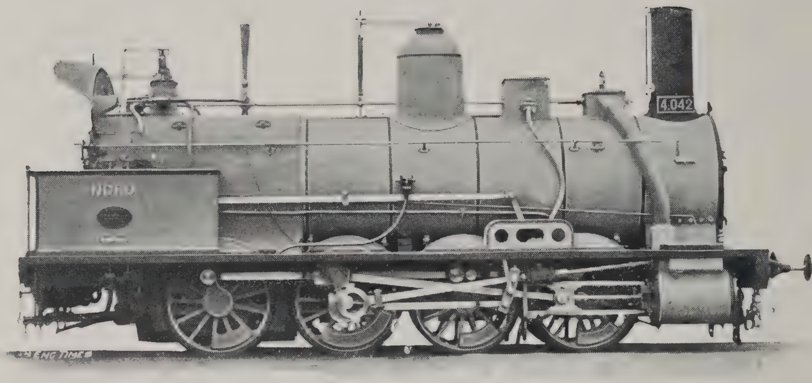


FIG. 5.—FOUR-COUPLED LOCOMOTIVE OF THE NORD RAILWAY (ORDERED, WITH BUT SLIGHT ALTERATIONS, FROM 1866 TO 1890).

Grate area, 23 sq. ft. Diameter of Cylinders, 19⅝ in. Stroke of Pistons, 25½ in.
Diameter of Wheels, 91 in. Weight in running order, 44 tons.

this class, with two cylinders, were designed in 1875 by Mr. A. Mallet for the Bayonne-Biarritz Railway; they were found handy and economical, and are still running.

Fig. 7 gives an example of the four-cylinder compound locomotives, with two coupled axles and a bogie, which are used on all large railway systems in France. In order to increase the dimensions of the boilers of these high-speed engines with two driving axles, the type called "Atlantic," with a carrying axle added behind the driving axles, has been recently introduced, with excellent results, on the Nord Railway (Fig. 8). A special feature of these "Atlantic" locomotives is the shortness of the coupling rods, which are very long when the fifth axle is not used.

Another very interesting type of engine, which has lately found great favour in France as in other countries, is the three-coupled locomotive, with somewhat large diameter of wheels and bogie in front; the four-cylinder compound system adapts itself very nicely to this arrangement. The range of utility of these engines is very wide, as they are found, in many cases, able to manage nearly all the traffic of a railway, with the exception of the fastest expresses and of the suburban trains. Their use corresponds to an increased speed of goods and mineral trains, which is advisable on crowded lines, as already stated, to avoid long delays on side tracks in stations. After the experience of the P. L. M. and Nord Railways, the better utilisation of men and rolling

FIG. 6.—THREE-COUPLED TANK LOCOMOTIVE OF THE OUEST RAILWAY (ORDERED WITH SLIGHT ALTERATIONS, FROM 1883 TO 1896).

Weight in working order, 41 to 42 tons.

stock largely compensates for the slight increase in other expenses which may result from this practice.

The diameter of the driving wheels varies in France from 1·600 to 1·750 m., and more in a few cases (5 ft. $2\frac{15}{16}$ in. to 5 ft. $8\frac{7}{8}$ in.). With an increase up to 2 m., this class of engines would, very likely, be suitable for the highest speeds. Fig. 9 shows one of these locomotives.

Mention must be made of a two-cylinder compound, which is used on the Midi Railway with good results. It is an old three-coupled locomotive, being either two or three), may be summed up as follows:—

First of all, better utilisation of steam results from the compound system, either with two, three, or four cylinders, although the common slide-valve continues to be used. Another benefit of the compound system, which may be called indirect, is the possibility of conveniently using a very high initial steam pressure.

With the four-cylinder system the strain on each individual mechanism is largely reduced. Owing to the very

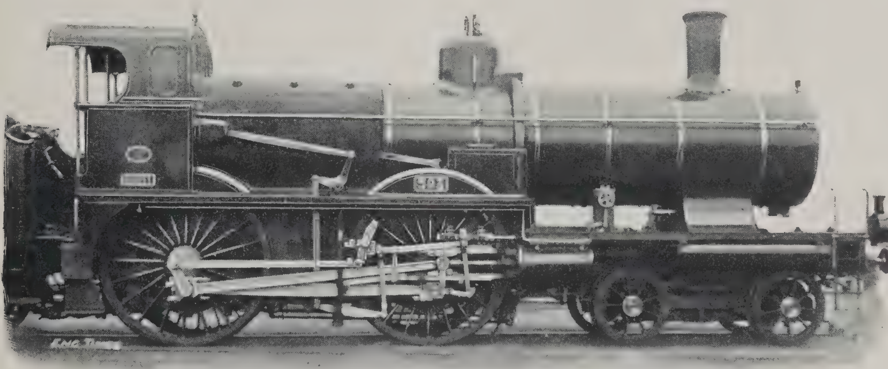


FIG. 7.—COMPOUND FOUR-CYLINDER EXPRESS LOCOMOTIVE OF THE OUEST RAILWAY (ORDERED IN 1897).

Grate area, $25\frac{13}{16}$ sq. ft. *Heating surface, $1439\frac{3}{16}$ sq. ft.* *Boiler pressure, 199 lb. per square inch.*
Cylinders—2 high pressure, $13\frac{3}{8} \times 25\frac{1}{8}$ in.; 2 low pressure, $20\frac{7}{8} \times 25\frac{1}{8}$ in. *Diameter of Driving Wheels, 6 ft. $7\frac{1}{8}$ in.*
Total weight in working order, 48·72 tons. *Adhesive weight, 30·51 tons.*

rebuilt with a pony truck (of one pair of wheels) in front of the outside cylinders.

On heavy grades, the P. L. M. uses four-coupled engines, without carrying wheels; they are four-cylinder compounds, the four cylinders being placed side by side in front of the first pair of wheels, of which the diameter is 1·500 m. (4 ft. $11\frac{1}{16}$ in.). Twelve years ago the Nord ordered a lot of twenty four-coupled locomotives with tandem cylinders.

The advantages of the four-cylinder compound locomotive with two axles separately driven by the two groups of cylinders, but united by coupling rods (the total number of coupled axles limited available space, it is difficult, in an ordinary locomotive with two cylinders, either inside or outside, to provide sufficient surface for the wearing parts, when high power is required, as in modern construction. The practical consequence has been that, whilst ancient locomotives, with small cylinders and low pressure of steam, could make very long mileages without repairs, the wear became surprisingly rapid in new locomotives with big cylinders and high pressure. With the four separate cylinders plan, the pressure and the strains being divided in two, the old favourable conditions reappeared.

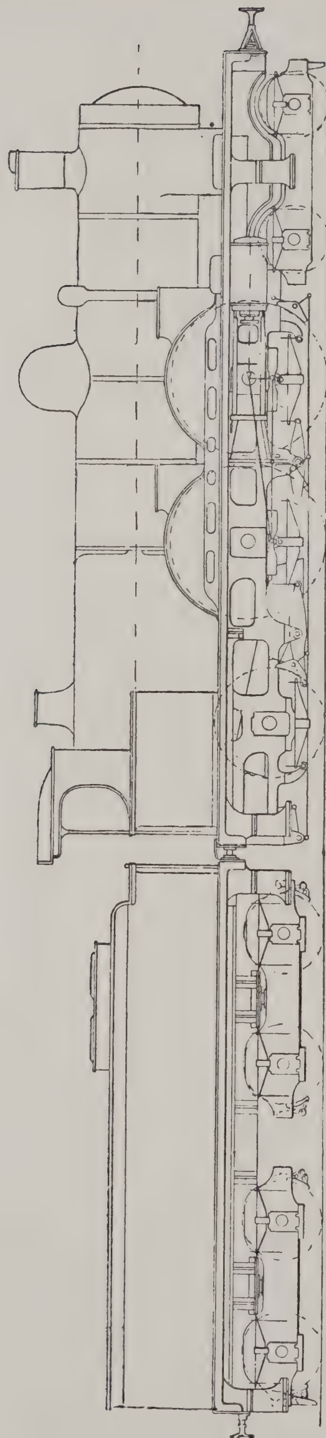


FIG. 8.—COMPOUND FOUR-CYLINDER EXPRESS LOCOMOTIVE OF THE NORD RAILWAY "ATLANTIC" TYPE (ORDERED IN 1898).

Grate area, $29\frac{1}{2}$ *sq. ft.* *Heating surface*, $2274\frac{1}{2}$ *sq. ft.* *Boiler pressure*, 228 *lb. per square inch.* *Cylinders*—2 *high pressure*, $13\frac{3}{8} \times 25\frac{1}{4}$ *in.*; 2 *low pressure*, $22 \times 25\frac{1}{4}$ *in.*

Diameter of Driving Wheels, 6 *ft.* $8\frac{5}{16}$ *in.* *Total weight in working order*, 63 *tons.* *Adhesive weight*, 32·48 *tons.*

An important point of the system is the good equilibrium of the reciprocating parts, which means smooth running, and, combined of course with the use of a suitable bogie, an important reduction of the stresses which the permanant way has to bear.

Very large available power at starting is owing to the possibility of admitting live steam (at reduced pressure) in the low-pressure cylinders, with a direct exhaust for the high-pressure ones; in fact, the adhesive weight could hardly allow the full utilisation of the tractive power thus obtained, and this working, where steam is somewhat wasted, is seldom resorted to, except in some cases for the first turns of the wheels. It would be a mistake to suppose that the economy of the compound system is seriously impaired by this device.

It is quite easy to work the four-cylinder compound either at low or at high speed. For instance, express locomotives have been found quite able to haul heavy mineral trains on flat lines. On the other hand, with a properly designed steam distribution (sufficient clearance and negative inside lap), no difficulty has prevented the running at the highest speeds ever used on railways.

It must be understood that the reality of these advantages is proved by an extensive experience on all large French railway systems, and that nearly everyone who has had opportunity to watch the working of these locomotives adheres to the same opinion in this respect, from the locomotive superintendent down to the engine cleaner.

One point, which is certainly above dispute, is that this class of locomotives makes an excellent service; it is possible to imagine that simple two-cylinder locomotives might do the same work, but these do not seem to exist in France, and probably they would be heavier. As regards economy of these four-cylinder

compound locomotives, compared with simple engines of the same weight (and this is hardly a fair basis of comparison), the initial cost of the compound is a little higher; the expenses for repairs may be about the same, the greater number of parts being compensated by the reduction of strains on each separate mechanism; the coal consumption is certainly less by 10 to 15 per 100. Taking all into account, the cost for the same work done is certainly not larger with the compounds. Coming to actual practice, as the rational working of railways generally require the locomotives to be used to their utmost capacity as frequently as possible, if the simple locomotive was to perform the same work as the compound, this could not be done without forcing the production of the boiler to such an extent that it would involve an extravagant coal consumption.

Amongst recent non-compound locomotives in France may be mentioned sixty small tank engines ordered by the Nord Railway, with two coupled axles, outside cylinders, and a bogie in front. Recently the Ouest has ordered twenty-five powerful tank locomotives with three-coupled axles and a bogie (Fig. 10), having outside cylinders and valve-gear. These locomotives are remarkable for their large capacity in storing water and fuel, often too limited in tank engines. This enables them to run considerable distances, and makes them suitable for a large number of passenger and goods trains. During some trials, one of these locomotives has attained a speed of 118 kilometres ($73\frac{1}{3}$ miles) per hour, although the diameter of the wheels is only 1·510 metre (4 ft. $11\frac{7}{16}$ in.). The outside position of the mechanism is very handy; when it is inside, the side tanks render access difficult.

Narrow gauge locomotives, specially for one-metre gauge, are numerous in France, and interesting. In many cases, the simplest forms of tank engines, with side tanks and outside cylinders, are used. But, as sharp

FIG. 9.—COMPOUND THREE-COUPLED LOCOMOTIVE OF THE OUEST RAILWAY (ORDERED IN 1898), WITH FOUR CYLINDERS.

Grate area, $26\frac{3}{8}$ *sq. ft.* *Heating surface*, $2088\frac{1}{4}$ *sq. ft.* *Boiler pressure*, 199 *lb. per square inch.*
Cylinders—2 high pressure, $13\frac{3}{4} \times 25\frac{1}{8}$ *in.*; 2 *low pressure*, $21\frac{5}{8} \times 25\frac{1}{8}$ *in.* *Diameter of Driving Wheels*, 5 *ft* $7\frac{11}{16}$ *in.*
Weight in running order, 57·48 *tons.* *Adhesive weight*, 40·84 *tons.*

curves happen frequently on these lines, flexible locomotives of the Mallet system have sometimes been adopted. In these engines (Fig. 11), the main frame carries the boiler and two high-pressure cylinders, driving the rear group of coupled wheels; a truck, movable round a pin fixed at about the middle of the length of the engine, supports two low-pressure cylinders, driving the front group of coupled wheels. The flexible pipes, connecting the truck with the main frame, support are usually made of stamped wrought iron after the Arbel type; but there are some good reasons to believe that these iron wheels will not be used much longer.

As already remarked, bogies are frequent. Whilst at the International Exhibition of 1889 only locomotives of the Nord and Ouest in the French section were furnished with bogies, engines are no longer constructed in France without one, unless for suburban or shunting service.

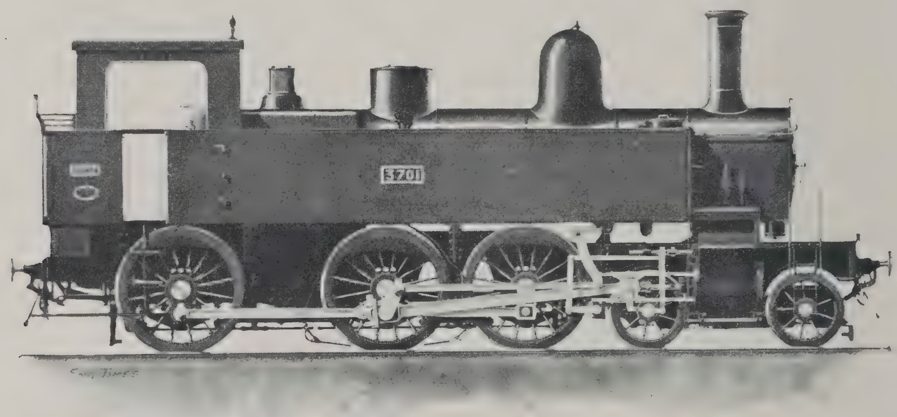


FIG. 10.—BOGIE TANK ENGINES FOR THE OUEST RAILWAY.

Grate area, $19\frac{3}{8}$ sq. ft. *Heating surface, $1416\frac{9}{16}$ sq. ft.* *Boiler pressure, 171 lb. per square inch.*
Diameter of Cylinders, $18\frac{1}{8}$ in. *Stroke of Pistons, $23\frac{9}{16}$ in.* *Diameter of Driving Wheels, 4 ft. $11\frac{7}{16}$ in.*
Capacity of Water-Tanks, 1540 gals. *Capacity of Coal-Bunkers, 2·46 tons of coal.*
Weight in running order, 57·97 tons. *Adhesive weight, 43·21 tons.*

only the receiver pressure; there is no difficulty in providing a movable joint for the exhaust pipe. There is, of course, no objection to the use of the Mallet system for ordinary gauge locomotives; this application has been successfully made in several cases.

Attention will be called to some details which specially characterise present French construction. In the frames, for parts such as cross ties and slide-bar brackets, cast steel is frequently employed. Cast steel has been rarely used in France for wheels, which

The former bogie of the Nord had a fixed pivot, whilst that of the Ouest had a lateral movement; the latter arrangement is now always adopted, the lateral play being controlled by springs. The bogie of the Ouest, with internal frames, is still one of the simplest on French railways.

In recent construction, the Walschaerts gear has been largely used for the valve-motion. This kind of gear is simple and quite suitable for outside cylinders with valves on top (Fig. 12); it is also convenient for inside cylinders with

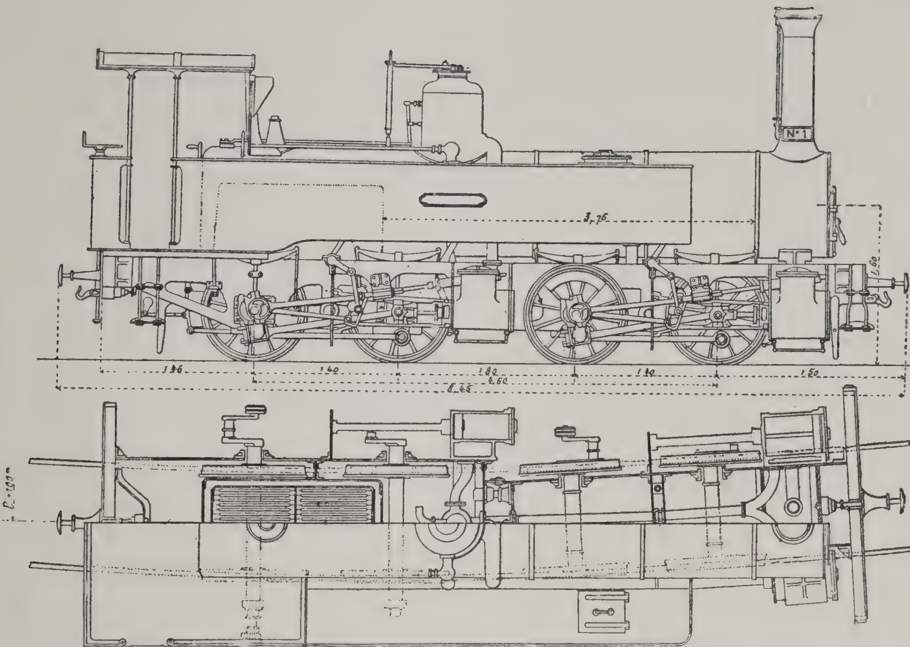


FIG. 11.—MALLET COMPOUND LOCOMOTIVE FOR ONE METER GAUGE, DESIGNED IN 1885.

valves on inclined tables slanting outwards from the top. It gives an equal distribution of steam on both sides of the piston, because the motion of the valve is partly derived from the crosshead, thus entirely eliminating the disturbing influence due to the obliquity of the connecting rod.

Cylindrical valves were applied many years ago to locomotives on the Etat system, but this mode of construction has spread but little in France. The Adams balanced valve has been used on a considerable number of locomotives on the Nord. The Est for some years past has made trials of this valve, and

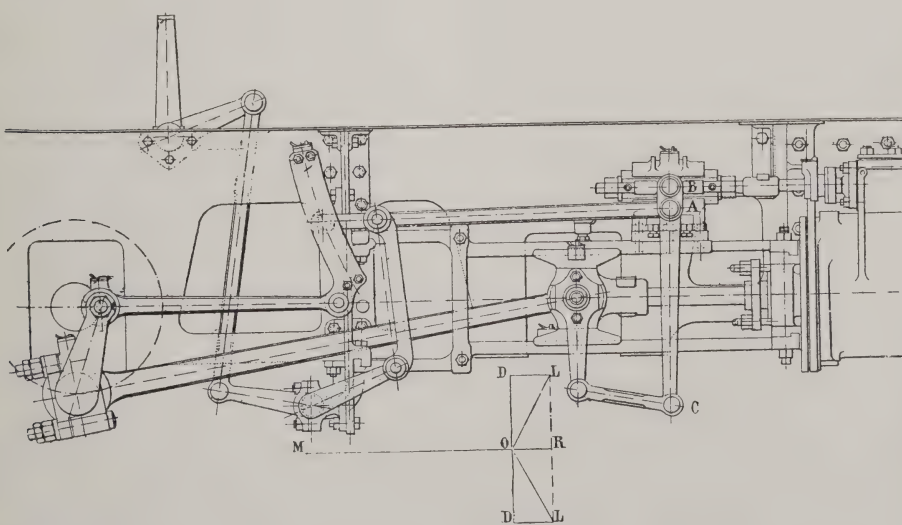


FIG. 12.—WALSCHAERTS GEAR FOR VALVE MOTION THE CENTRE OF THE VIRTUAL EXCENTRIC VARIES FROM L TO L.

of the Richardson American valve. The latter railway is preparing an experiment on cylindrical valves. The general adoption of the compound system, which reduces the pressure on ordinary valves, may explain why these arrangements have been somewhat neglected in France.

For oiling the valves and pistons, a kind of oil pump is generally preferred, as it gives a very uniform flow of oil, which can be regulated at will.

In the four-cylinder compound locomotives, two lifting-shafts, one for the two high-pressure, the other for the low-pressure cylinders, are generally actuated by two reversing screws placed close together; the two can be reversed at will, either together or separately. The drivers are thus able to adjust suitably the distribution for all requirements, and have found from practice, in a short time, the best working positions. Admission of steam to the low-pressure cylinders should always be at least from 40 to 50 per cent. of the stroke, and later for high speeds.

On the P. L. M. the reversing-shafts are, on the contrary, actuated at the same time, so that they always take the same fixed relative position.

The starting apparatus usually consists of a large cock, which can interrupt the passage from the small to the large cylinder, and which opens at the same time a direct escape for the small cylinders. A similar cock exists on each side of the engine. The opening of this cock transforms the locomotive in a simple four-cylinder engine; in case of injury to one group of cylinders, it renders possible working with the other group only.

The system of the Est consists of a special box furnished with a flap-valve, which serves to separate the high-pressure and low-pressure cylinders, and a valve which opens a direct escape for the former. This apparatus receives the exhaust pipes from both high-pressure cylinders.

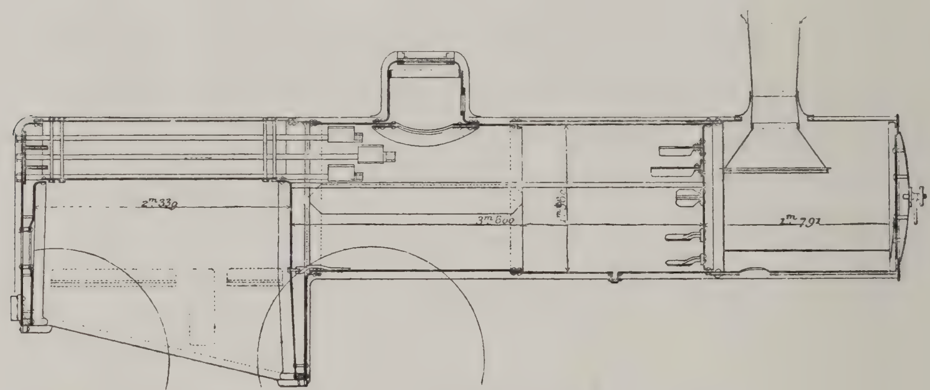


FIG. 13.—TYPICAL BELPAIRE BOILER OF A FRENCH LOCOMOTIVE.

New boilers are most often of the Belpaire type, the crown plates of the inside and outside shells being horizontal and stayed together (Figs. 13 and 14). The ordinary side stays are made of copper, and perforated on their whole length, the hole being plugged from the outside.

For some years ribbed or *Serve* tubes have been in general use (Fig. 15). These tubes are generally 70 millimetres ($2\frac{3}{4}$ in.) external diameter. The trials made in the workshops of the P. L. M. and of the Nord have shown that these tubes were just as

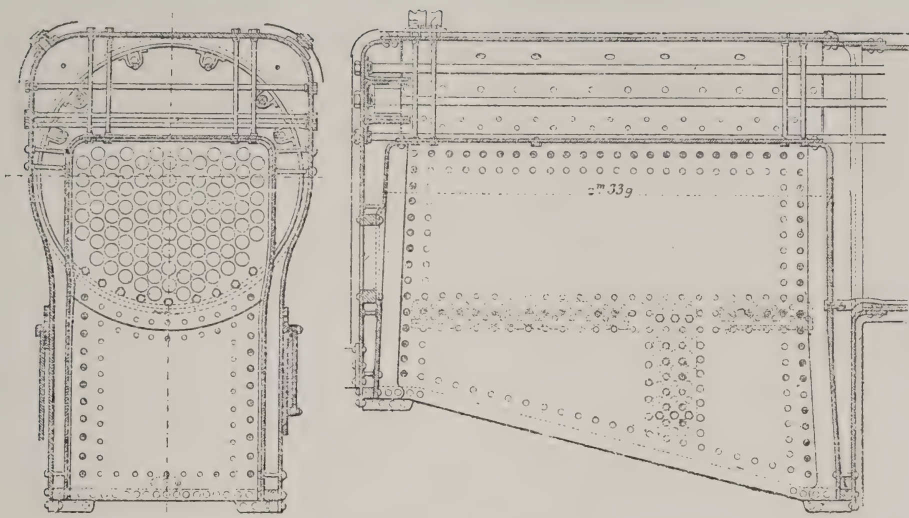


FIG. 14.—DETAILS OF BELPAIRE FIRE-BOX.

suitable as ordinary tubes having the same internal surface in contact with the hot gases; the results obtained in service confirm these trials. The tube plates appear to last longer with these big tubes, because the distance between the holes is generally larger than with the ordinary tubes. On the other hand, one might have anticipated that the ribbed tubes would have an injurious action upon the plates, because they expand more than ordinary tubes. the ribs being more highly heated; but no inconvenience due to this cause appears to have been proved in France. For cleaning these tubes, a jet of steam is

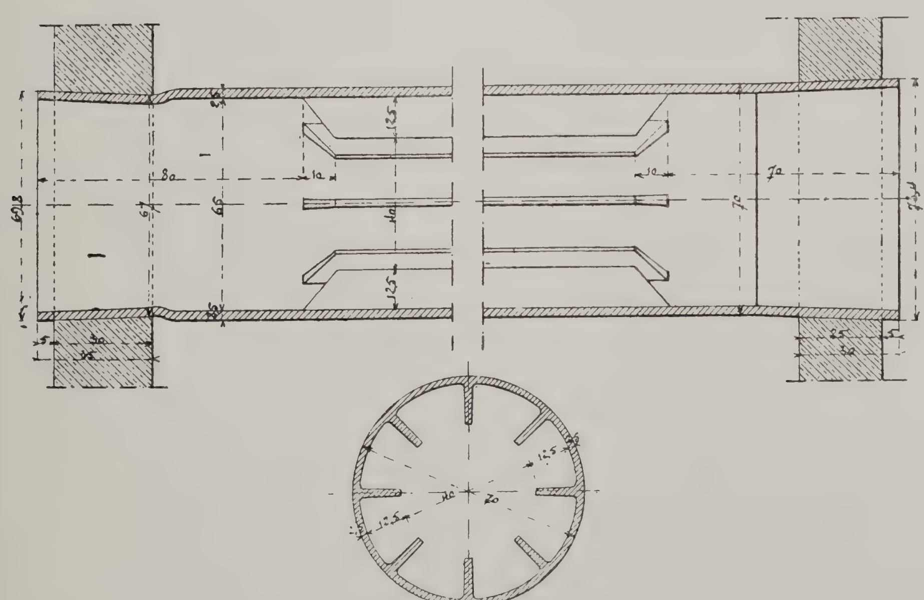


FIG. 15—SECTION OF SERVE OR RIBBED TUBE.

generally employed; but this jet does not always suffice, and it is necessary from time to time to clear out the deposits of coke from between the ribs.

Boilers are frequently constructed of mild steel plates; the fire-boxes are of copper. The trials of steel fire-boxes do not appear to have given any economy, although the saving in weight is important.

Direct-acting safety-valves (Adams, Lethuillier-Pinel, etc.) are more and more replacing the old arrangement with a lever; these valves, if not kept in very good order, are liable to give excessive escapes of steam.

In former French construction the barrel of the boiler rested on an intermediate support, which is now frequently omitted, the boiler being carried only by the smoke-box and the fire-box.

The injectors are often of the Sellers or Friedmann lifting type. They are not unfrequently mounted upon the fire-box back-plate, with an internal delivery pipe.

A special feature of the recent boilers is the extended smoke-box, whose length is about 2 m. or 7 ft. The object of this extension is to provide room in the box for the cinders without choking the lower tubes. With an active combustion, the quantity of these cinders, consisting of ashes and small pieces of coke, is sometimes very large at the end of a long run. A wire screen is provided to prevent the escape through the chimney of the biggest pieces, the use of this screen being compulsory in France.

The exhaust usually takes place between two movable flaps, giving a variable section. This variable exhaust can be easily adjusted to the proper size, according to the service of the locomotive and the quality of the coal; besides, at the end of a long run, if the grate is partly choked by slags, a very powerful blast is required. The drawback of this device is that, although a very simple piece of mechanism, it is liable to stick after a short service, owing to the accumulation of a kind of very hard soot.

Not much need be said of the tenders. They rest on two or three axles, and, in a few cases, on two bogies, according to the weight of coal and water. The use of the Ramsbottom scoop, for picking up water, is yet very limited in France; the Etat system has recently adopted it.

In concluding, it is worth mentioning that elegance in the design of locomotives now receives much more attention in France than formerly.

C Sauvage

AMERICAN LOCOMOTIVE PRACTICE.

By GEO. L. FOWLER.

THE American locomotive, as it stands to-day, is essentially an example of the product of the United States that has been developed along the lines laid down by the requirements of the service which it has been called upon to perform. The earliest engines used in America were imported from England, but their wheels had hardly started to turn before manufacturers of machinery in the United States began to direct their attention to locomotive construction and design. At first, as was quite natural, the work was done in partial imitation of what had been imported; but it was soon found that the wheel arrangement and the details of the construction of the machinery of the English engines could be advantageously modified.

The result was that during the forties there were numerous attempts made at improvements; some were valuable, some absurd, and others almost fantastic. Various types of wheel arrangements were tried and discarded, until along in the fifties the standard design had settled down to be an eight-wheeled engine, with four wheels coupled and a bogie truck in front.

At first these engines were built with the cylinders between the frames, but the trouble that was experienced in the manufacturing and maintaining of the crank axles, together with the crowding of the machinery into that narrow space, soon led to the spreading of the cylinders and the placing them outside the frames, with the connections taking hold of crank pins placed directly in the driver centres. This change gave some annoyance at first owing to the inclined position of the cylinders. It was soon remedied, however, by bringing the cylinders down into a horizontal position, and the engine thus became practically standardised.

This type of locomotive was then used for many years in all classes of service—freight, passenger (both express and local), work trains and construction. It was put to work on the prairie and on the mountain, and on tracks in all sorts of conditions of maintenance, and answered the purpose remarkably well, so long as the rails were light, the road-bed unequal to the carrying of heavy loads; and managers had not learned the economy of large trains and high-capacity cars.

In 1870 the average weight of these engines was about 35 tons, with perhaps 25 on the driving wheels. The attitude taken by the master mechanics at that time, was that the weight of engines had attained such enormous proportions that a further increase was out of the question, and that the next step in advance would be in the direction of a reduction of that weight.

At this time wood, which for many years had been the fuel used, was disappearing, and since 1870 bituminous coal has been the only recognised fuel on locomotive engines, except in the case of those working in the anthracite regions.

During the years from 1870 to 1880, a

great deal of work was done all along the line of railroad improvement. Steel rails became standard practice, and steel plate was almost universally adopted for boiler construction. Iron was still extensively used for axles and the working parts of the machinery, but the use of steel was extending, and exerting an influence on design.

Up to this time, with the exception of the anthracite burning engines which will be mentioned later, the fire-box was set down between the frames and between the driving axles. As the frames were of bars usually about 4 in. wide; as 8 ft. was considered a long wheel-base; and as the fire-box must needs clear the excentrics at the front and the axle-boxes at the rear, it was necessarily very narrow and short. Such fire-boxes, even with a 9 ft. wheel-base, would scarcely have more than 18 sq. ft. of grate area, while the heating surface of the boiler lay between 1,100 and 1,200 sq. ft. The cylinders of such engines were usually 16 in. in diameter, with a piston stroke of 24 in., working with a boiler pressure of 125 lb. per sq. in.

The demand for faster service, coupled with the increasing weight of trains, forced an issue, and in 1881 a great step in advance was taken. Mr. Theo. N. Ely, who was at that time superintendent of motive power of the Pennsylvania Railroad, had the courage of his convictions, and raised the boiler so that the foundation ring of the fire-box was placed on top of the frames. Many were the dire predictions that were made regarding the fate of this top-heavy engine, known as Class K. In fact, the sound of the croaker was so loud that, despite the fact of the most careful calculations showing perfect stability, even the minds of the officials were affected, and on the first run from Altoona to Harrisburg, the speed was limited to 40 miles an hour. The engine, however, was so steady that on the return trip a speed of 60 miles an hour was run over some of the sharpest curves of a very crooked road. The machine did not upset, it did not leave the rails, and a new era in locomotive building was inaugurated.

This change made an indefinite extension of the length of the fire-box possible, a length that was only limited by the ability of the fireman or stoker to handle the fuel and place it properly. The result of this is that the dimensions have increased to a length of as much as 12 ft. The width, however, has still been limited in this design to what can be worked in between the tyres of the driving wheels.

With the increase in the size of the fire-box came a corresponding increase in the heating surface, the diameter of the shell, and the pressure of steam. The heating surface advanced by 100 sq. ft. at a time; tubes were lengthened from 11 ft., until now 16 ft. are used; and the shell has even touched a diameter of 6 ft.

The form of the boiler underwent many modifications. The waggon-top has been flattened and extended until it now reaches well out over the shell. Frequently the straight-top boiler is used where the great size and height of the shell renders any further rise impossible. The crown-bar method of supporting the crown-sheet of the fire-box has disappeared from general practice, and this part is now held by radial stays, or is built on the Belpaire design.

The steam pressure has been raised from that of 20 years ago at 125 lb. to an average for general practice of about 180 lb., with a use of 200 lb. so frequent as to excite no comment.

The weights of engines have also risen from the 35 tons of thirty years ago to a maximum of 125 of to-day. The proportion of light engines weighing less than 100,000 lb. is daily growing less.

All of the advantages that could be

"ATLANTIC" TYPE OF EXPRESS PASSENGER LOCOMOTIVE FOR BURNING ANTHRACITE COAL, BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

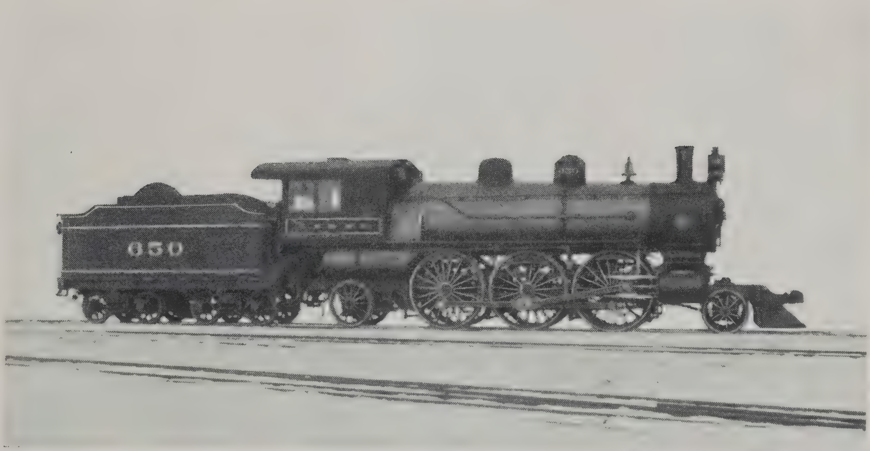
"AMERICAN" TYPE OF EXPRESS PASSENGER LOCOMOTIVE FOR BURNING ANTHRACITE COAL BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

gained by the location of the fire-box above the frames were obtained by 1891, and builders began to cast about for the means of still further increasing the power of the express locomotive. This meant an increase of boiler capacity, which could only be brought about by an increase of grate area and of heating surface. The result of this pressure is found in what was known as the "Columbia" type of engine, in which there were four driving wheels, all set in front of the fire-box, with a two-wheeled truck at the forward end, and a pair of rather large trailing wheels under the foundation-ring. This was at once superseded by the "Atlantic" type, in which a four-wheeled truck was substituted for the one with two wheels. This gave a further opportunity for an increase in the width of the fire-box. By successive modifications in the construction of the frame and the design of the axle-boxes for these trailing wheels, a width of more than 6 ft. has been obtained, while a length of 9 ft. makes the proper handling of the fuel well within the capacity of the fireman. This gives a grate area of 54 sq. ft. Such a boiler would have about 2,800 sq. ft. of heating surface, would carry a pressure of 210 lb. per sq. in., and supply steam for cylinders 20 in. in diameter, and having a piston stroke of 26 in.

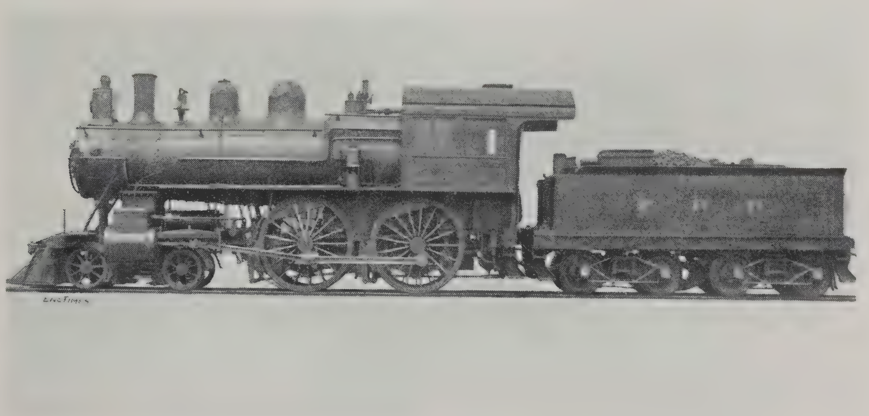
What has thus far been said applies more particularly to the developments of the passenger locomotive. The work on the freight engine has, however, not lagged behind. With the improved facilities for running heavier rolling stock, it was soon evident that great economies could be effected by increasing the tractive power of the locomotive. The first step was naturally that of adding to the weight of the eight-wheeled or American type. What was considered a safe load for the wheels was soon reached, and still it was desired to increase the availability of the power that the boiler could produce. This brought about the re-introduction of another form of eight-wheeled engine, in which there were three pairs of driving wheels, led by a "pony" or "bissel" truck having a single pair of wheels. Such an engine was nicknamed a "Mogul," and such it has been called ever since.

Further demands for an increase of power led to the addition of another pair of driving wheels, and the last form of freight locomotive, or the "Consolidation," was brought out. This has four pairs of driving wheels with a pony truck at the front. It is one of the heaviest class of freight locomotives, and is used as the standard on the majority of American railroads; the heaviest having a total weight of 250,300 lb., of which 225,200 lb. are upon the driving wheels. These engines have cylinders 24 in. in diameter and a piston stroke of 32 in., working with a boiler pressure of 180 lb. per sq. in.

Owing to a prejudice that is wholly unwarranted by the facts of the case, the "Mogul" type of engine is not a popular one for passenger service, although it is frequently so used. There is a fear regarding the liability of the pony truck to leave the rails at high speeds, which is not based upon one iota of evidence that it has ever done so. The matter has been discussed repeatedly before the American Railway Master Mechanics Association, without provoking a single statement that such a derailment has ever occurred. However that may be, the fact of the existence of the prejudice remains, and it has led to an extensive use of what is known as a "ten-wheeled" locomotive. These engines have six wheels coupled and a regular four-wheeled bogie truck at the front. They are extensively used in both freight and passenger service, and, on some roads, the work is done interchangeably with the same engine. They



FAST PASSENGER LOCOMOTIVE, BUILT BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, NEW YORK.

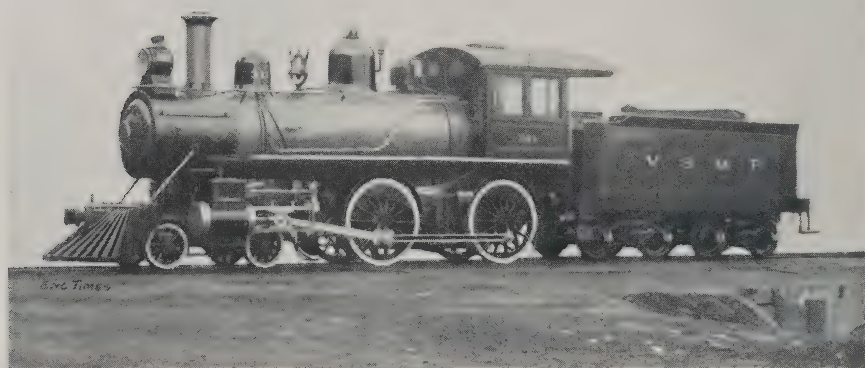


"AMERICAN" TYPE OF EIGHT-WHEELED EXPRESS PASSENGER LOCOMOTIVE, BUILT BY THE PENNSYLVANIA RAILROAD AT THE ALTOONA SHOPS.

are admirably adapted for work on high speed passenger trains where the load is heavy, and they are capable of making very fast time.

While these four classes may be said to cover the majority of the engines in use upon American railroads, they by no means include all of the wheel arrangements that have been built. These have run nearly the whole ground of the possibilities of the case, and have been adapted to meet a very wide range of special requirements. To even catalogue all that has been done in this respect would require far more space than the limits of this article will allow.

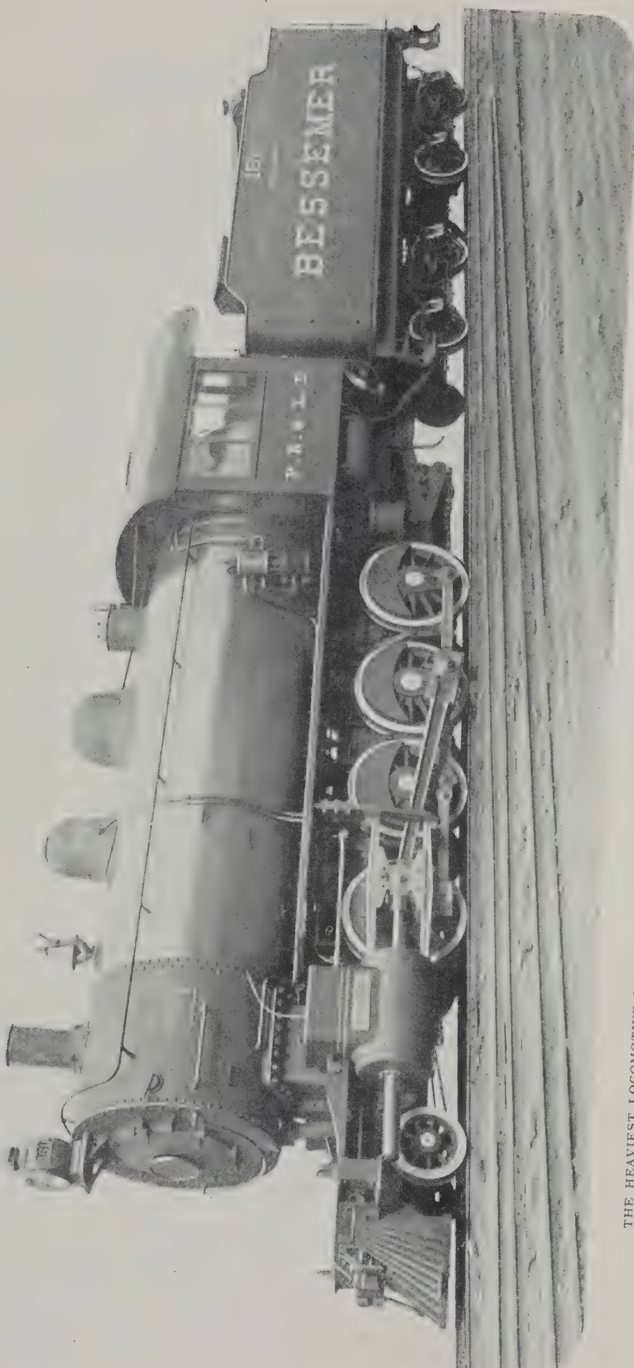
In the matter of the weights of locomotives used in the United States, these vary like the size of a piece of cheese. As already stated, the average of these weights has been greatly increased during the past thirty years, and now ranges between wide limits. As a statement of the general average of weights of the five classes, as they are used upon the principal roads, it may be said that the eight-wheeled or American type will have cylinders 19 in. in diameter with a piston stroke of 24 in., and will weigh about 127,000 lb., of which 87,000 lb. will be on the driving wheels. The "Atlantic" type will have 20 in. by 26 in. cylinders and will weigh 162,000 lb., of which 87,000 lb. are on the drivers; the ten-wheelers will have 20 in. by 26 in. cylinders, and will weigh 145,000 lb., of which 109,000 lb. are on the drivers; the "Mogul" will have 20 in. by 24 in. cylinders, and carry 109,000 lb. on the drivers out of a total of 125,000 lb.; and the "Consolidation" with 20 in. by 26 in. cylinders will weigh 146,000 lb., and have 129,000 lb. on the drivers.



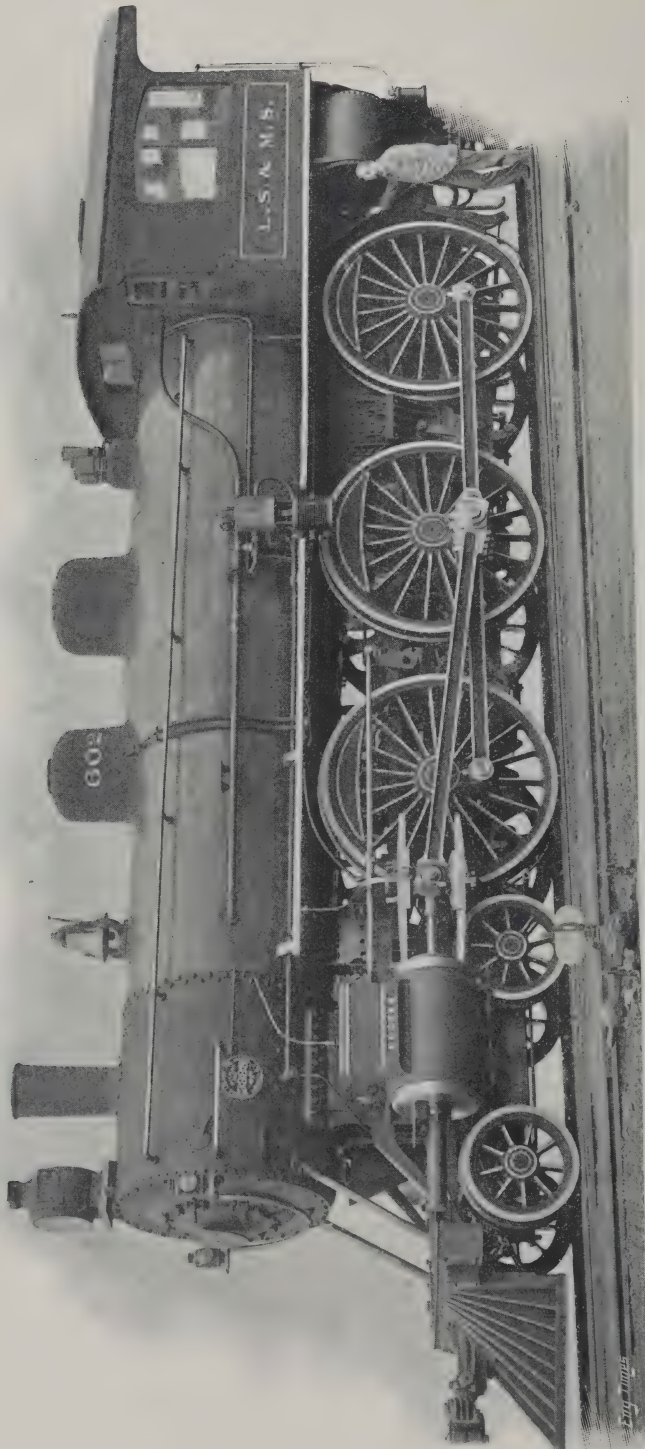
EIGHT-WHEEL "AMERICAN" TYPE LOCOMOTIVE, BUILT BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

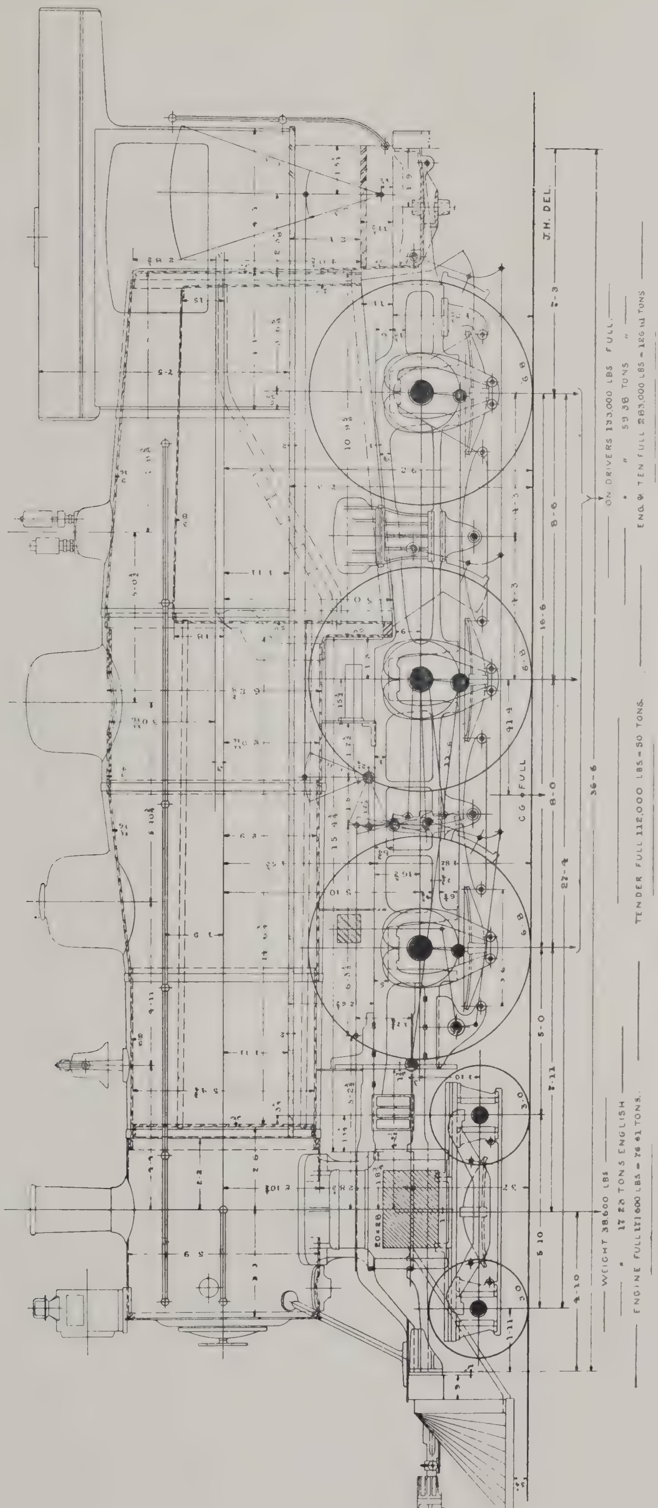
The rating of these engines varies within wide limits, according to the service; in some cases running as high as 4,000 tons for the load behind the tender.

Up to this point the engine has been considered solely as a burner of bituminous coal. In the anthracite coal regions, that fuel is universally used. The requirements are that there shall be a very large grate and a comparatively low rate of combustion. As a shallow fire can be worked, the fire-box used is invariably of the "Wootten" type, usually with the combustion chamber omitted. These fire-boxes are very wide, often



THE HEAVIEST LOCOMOTIVE IN THE WORLD, BUILT BY THE PITTSBURGH LOCOMOTIVE WORKS, PITTSBURGH. WEIGHT, 250,300 LBS.





TEN-WHEEL EXPRESS PASSENGER ENGINE, BY THE BROOKS LOCOMOTIVE WORKS.

having a width of 7 ft. or more, and are set above the driving wheels. This, of course, necessitates a rather high centre for the shell, but the fastenings and arrangements are purely matters of minor details.

American engineers have also been hard at work at the solving of the problem of the successful construction of the compound locomotive. It is a curious fact, however, that with one or two exceptions the whole work of exploitation and development of the system has been done by the builders, with but very little assistance and still less encouragement from the railroad officials, who were most vitally interested in saving that would be effected. The builders have, however, worked hard, and each one has his pet scheme of compounding, protected by patents, which he exploits. As it is quite impossible to describe them all, one can be selected as typical of the practice, and which is now being extensively used. The one thus chosen is that built by the Richmond Locomotive Works, of Richmond, Virginia.

This system has been extensively advertised by means of an exhibition locomotive, yclept the "Tramp," that has been sent from one end of the country to the other, giving exhibitions and working in a service competition with the engines of the roads visited.

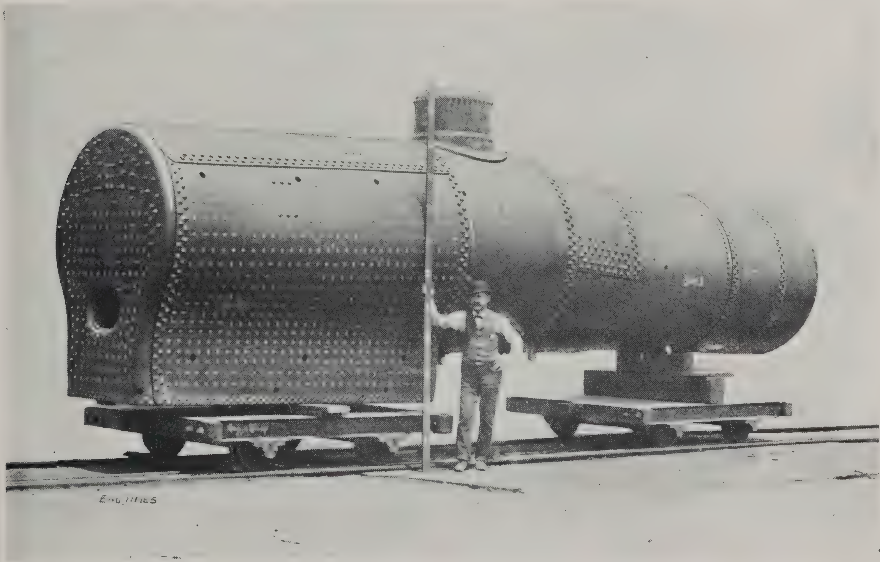
The engine is of the two-cylinder type, and its peculiarity lies in the construction of the intercepting or starting valve. This valve is located in the cylinder casting of the low-pressure cylinder. It is arranged to close at the instant of opening the throttle when starting, and thus cutting off the passage of the steam from the receiver to the low-pressure cylinder. At the same time a passage is opened from the boiler to the low-pressure cylinder, admitting steam to the latter at a reduced pressure, and enabling the engine to start. This reduction is entirely automatic, and the pressure in the large cylinder never exceeds the

"MOGUL" LOCOMOTIVE FOR FREIGHT SERVICE, BUILT BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

"CONSOLIDATION" LOCOMOTIVE FOR FREIGHT SERVICE, BUILT BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

predetermined amount. As the engine moves, the exhaust from the high-pressure cylinder passes into the receiver, and as soon as the pressure in the latter equals that in the large cylinder, the intercepting valve opens for the passage of steam from the receiver, closes the valve admitting live steam from the boiler to the low-pressure cylinder, and the engine works as a compound.

The intercepting valve is also provided with an emergency valve, by which the former can be held shut and the high-pressure exhaust allowed to escape into the atmosphere, thus working the locomotive as a simple engine as long as the driver may desire. It may be added, however, that this is only done at low speeds, and where a heavy load is to be moved. When the speed reaches seven or eight miles an hour,



BOILER FOR "CONSOLIDATION" LOCOMOTIVE, BUILT BY THE RICHMOND LOCOMOTIVE WORKS.

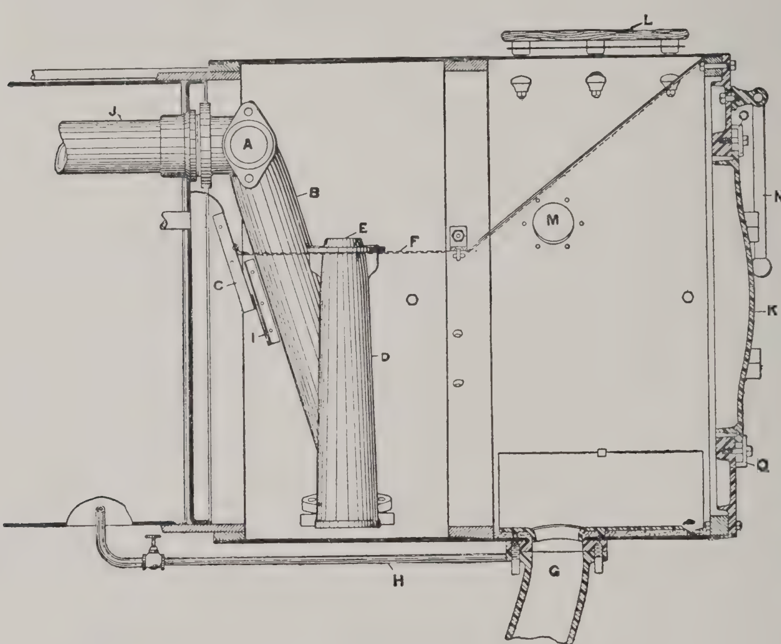
the exhaust becomes so choked that a further increase is impossible, and the driver is compelled to work it as a compound in self-defence. This prevents an abuse of the emergency valve, with the resulting wastefulness at the hands of a careless driver.

These engines are also provided with a by-pass valve that opens automatically when steam is shut off, and establishes a free communication between the two ends of the cylinder, thus preventing the fanning of the fire when the engine is drifting without the use of steam.

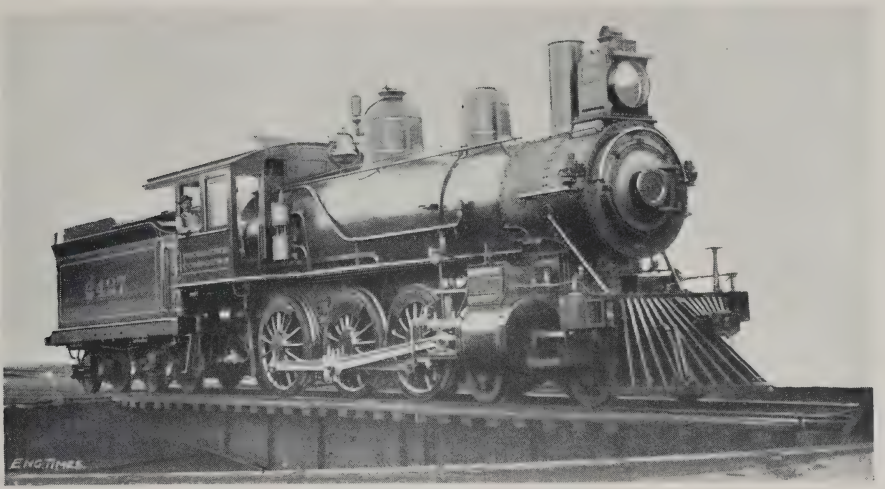
The coal saving that is effected by these engines varies between wide limits, according to the service, quality of coal, and design of the engine. The builders guarantee 15 per cent.; the engines have saved as much as 35 and more, and the average is from 22 to 25. They are extensively used over a wide range of territory, and many have been sent abroad, especially to the roads of Sweden and Finland.

The American locomotive, like those of Europe, is possessed of certain features and peculiarities that are its own. If, however, I were asked to name its most prominent and valuable characteristic, I should say it was to be found in the extreme simplicity of its construction and great accessibility of its parts. In the case of the ordinary engine there is hardly a bolt or a working piece that cannot be readily inspected from a pit or the ground.

There may be many reasons for this, but there is one which may possibly be considered a controlling one. For very many years, and indeed until very recently, the men in charge of the locomotive department of American railways were those who had worked their way up from the ranks of firemen, engineers, and machinists. As they had done the practical work of maintenance and repairs with their own hands, they appreciated the value of accessibility of parts as no one who had not received that training could possibly have done. The result of this training is, that the



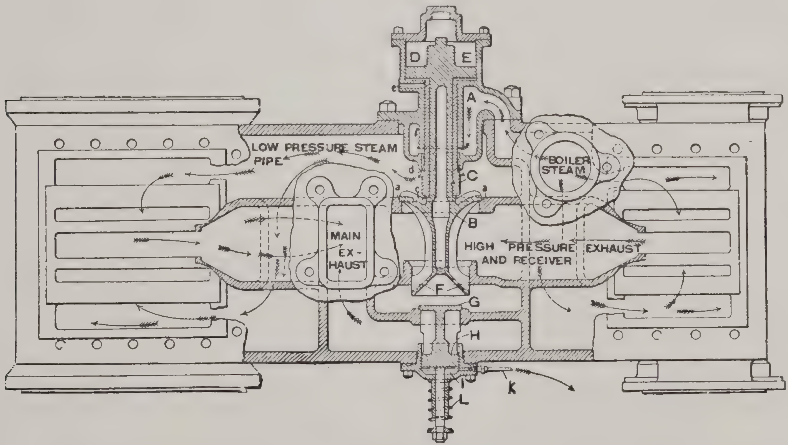
TYPICAL SECTION OF SMOKE-BOX OF AN AMERICAN LOCOMOTIVE.



TWO-CYLINDER, TEN-WHEELED COMPOUND LOCOMOTIVE "THE TRAMP," BUILT BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

American engine is a model of simplicity, and everything tending to a multiplicity or complication of parts is rigidly tabooed until it has most thoroughly demonstrated its value. Hence, in the case of the ordinary locomotive, it is quite possible for the engineer to make a pretty thorough inspection of the running parts of the machine even in the brief interval that is allowed for oiling at a station stop.

Turning from this general characteristic to details, we find, among other prominent features of these engines, that the cab is by no means an insignificant one. As in other countries, the early locomotives were built without cabs, on the ground that the locomotive driver could withstand the inclemencies of the weather as well as the stage driver. But it was soon learned that the parallel did not hold in the severities of the northern winters in America. Not only was a shelter needed, but a shelter which would so protect the men that they could devote all of their energies to



DIAGRAMMATIC ARRANGEMENT OF INTERCEPTING VALVE OF COMPOUND LOCOMOTIVE AS MADE BY THE RICHMOND LOCOMOTIVE WORKS.

their work without being concerned to any appreciable extent in their own creature comfort. The fact that the men in charge of the locomotive department had "been there" as firemen and runners no doubt contributed largely to the quick development of the shelter to a warm and comfortable cab, where the most careful attention is paid to convenience and ease. All of the levers and gauges are within reach of the engineer. He has a cushioned seat set on springs; the reverse lever is so balanced that it is easily moved; the brake valves, throttle lever, gauge cocks, sand valves and injectors can be operated as he sits by the window, and there is no excuse for any neglect of duty. He is not obliged to muffle himself until his movements are cumbersome even in the coldest weather, as the cab is warm enough to permit the wearing of ordinary clothing; while it can be so well ventilated that, during the hottest weather of the summer, there is no discomfort.

It is quite true that the American locomotive no longer stands alone in the use of the cab, but for many years it did.

At the other end of the machine we find the headlight and the pilot. The former is more effective as a warning to those on the ground than as a means of lighting the path of those on the engine. It is quite remarkable for how short a distance the headlight really illuminates the rails. While it can be seen for a distance of several miles, the oil light is scarcely sufficient to illuminate a telegraph pole beside the track at a distance of fifty rods in front of the engine. In fact, on a straight track and clear night, a car standing ahead could not be seen in time to stop a train running at forty miles an hour, before such an obstruction would be struck. The electric headlight that is now gaining a foothold is doing good service in this respect by actually illuminating the track for long distances in front of the locomotive.

The pilot was born and lives as the result of what the American considers his inalienable right to go where he pleases, and to allow his animals to wander wherever pleasant pasturage may offer. As this frequently leads to the use of the railway right-of-way as a thoroughfare and a pasture, it follows that the company must protect its trains against disaster, and this protection has taken the form of the pilot or "cow-catcher," which is "very bad for the coo," but has saved many a train from being wrecked by throwing the intruding cow off the tracks, and even into the adjoining fields.

Returning to the engine proper, we find that the bar frame is almost invariably used. It is formed of two rails, the upper being the heavier, connecting the pedestals in which the axle-boxes are placed. It is usually made in two sections, one extending to a point in front of the forward driving axle, where it meets and is bolted to the forward section that extends out to the front bumper beam, and to which the cylinders are bolted. For heavy engines this forward section is formed of two rails, but usually for cylinders under 20 in. in diameter a single rail is used. The width of the frame is usually about 4 in., with a depth for the upper rail of from 4 in. to 5 in. The material used has invariably been of wrought iron until very recently. Of late years the making of steel castings has reached such a degree of perfection that some frames have been made of this material. That matter is, however, still in the experimental stage, and a frame of steel casting is regarded as a novelty. The experimental condition is not one that arises from any doubt as to the efficiency of the metal, but from lack of experience as to whether a broken frame can be

readily welded with the rather meagre facilities that obtain in the majority of railroad shops.

A great deal of study has been put upon the fastenings for the frames, especially upon the cylinder connections. Considerable trouble has been experienced at this point, and this is particularly true with the large cylinders working under high pressures. Bolts and keys are the means used, and, on the whole, they are efficient.

While on the subject of steel castings, it may be mentioned in passing that, of late years, this material has received an extensive application in locomotive construction, where it can be used either as a substitute for expensive forgings or to lighten parts that would ordinarily be made of cast iron. These cover a wide range of details, such as driving wheel centres, foot plates, lifting shafts, rockers, equalisers, link hangers, and the like, with hardly a new design that does not contain some fresh application of this valuable material.

The cylinders are, of course, invariably made of cast iron. For very many years it has been the custom to make the cylinder and half of the saddle in one piece. This combination was so designed that it was reversible, and could be used upon either side of the engine. Lately, however, the internal stresses set up in such a complicated casting when made in large sizes, coupled with the trouble at the frame fastening already indicated, has led a number of designers to cast the saddle independently, and bolt the cylinders to the outside, thus making three pieces of moderate size rather than two very large ones.

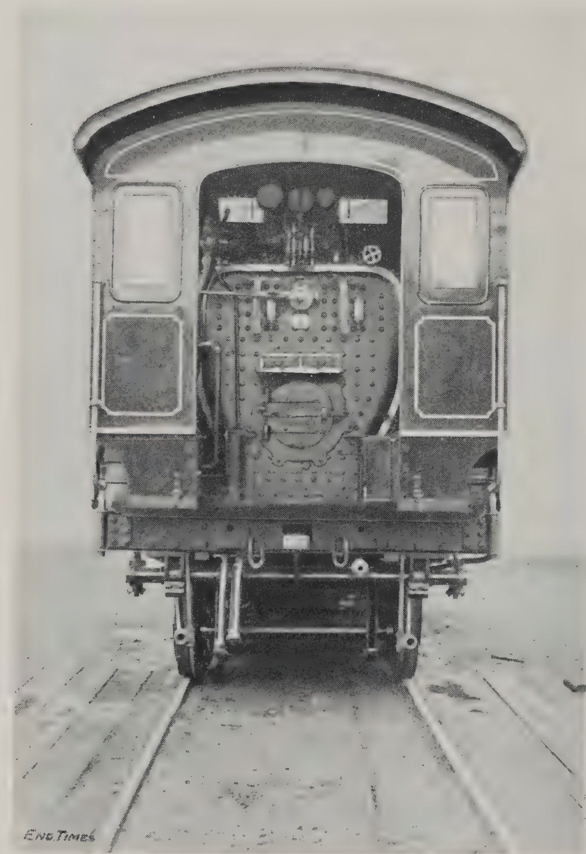
The smoke-box has also been the subject of a deal of experimentation, with the result that the internal arrangements have been greatly simplified. As now constructed, there is a diaphragm dropping down in front of the tubes, with a netting across the centre of the shell, and sloping up to the front end. The exhaust nozzle is, of course, above the netting, and is capped by a petticoat pipe or not, according to the diameter of the boiler and the distance of the stack opening above it.

As in the development of any piece of mechanism, the closest attention has been paid to the minor details of the locomotive, and there is hardly a part too insignificant to have been the subject of a report at the hands of a committee of the American Railway Master Mechanics'

SIX-WHEELED SWITCHING LOCOMOTIVE, BUILT BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VIRGINIA.

Association during the thirty-three years of its existence. To review this work and to state the reasons for the final adoption of the details as they now stand is of course quite impossible, and decidedly out of place in this connection.

In some particulars American railroad men and designers have been remarkably fortunate in the freedom with which they have been allowed to work. Legislation in the United States is rarely evoked except to check a flagrant evil. As a consequence of this spirit, there have been no statutory limitations as to speed. Whatever limitations of such a character are imposed have been voluntary on the part of the railroad officials themselves, and were dictated by common prudence. Thus, before the advent of the air brake a maximum speed of twenty miles an hour was a ordinary one for freight trains. Now even that has been removed, and forty miles is frequently touched on some roads. The selection of engineers or drivers has been conducted so judiciously that the men are not required to pass a licence examination by the State, and locomotive boilers are not subjected either to State or municipal inspection. All this is undoubtedly due to the great care that has been invariably exercised in these particulars, and the fact that the freedom has never been abused.



REAR VIEW OF LOCOMOTIVE, BUILT FOR THE YSTAD ESLOP RAILWAY, SWEDEN, BY THE RICHMOND LOCOMOTIVE WORKS, RICHMOND, VIRGINIA.

Finally, as for the work done. It will probably be conceded that American locomotives are worked as hard or harder than any others in the world. The result is that with the high rate of combustion upon the grate, often rising above 150 lb. of bitum nous coal of good quality per square foot per hour, and the high temperature of the smoke-box gases, the rate of evaporation is low, but the actual work done enormously high. Trains of from 2,000 to 4,000 tons behind the tender are of daily occurrence, and this frequently means as much or more than 2,000 tons of paying load. The speed of such trains will probably average from twelve to fifteen miles an hour over a division, including all delays and stops.

In passenger traffic the weight of train behind the tender is frequently 400 tons and over, scheduled for from 35 to 40 miles an hour over a division,

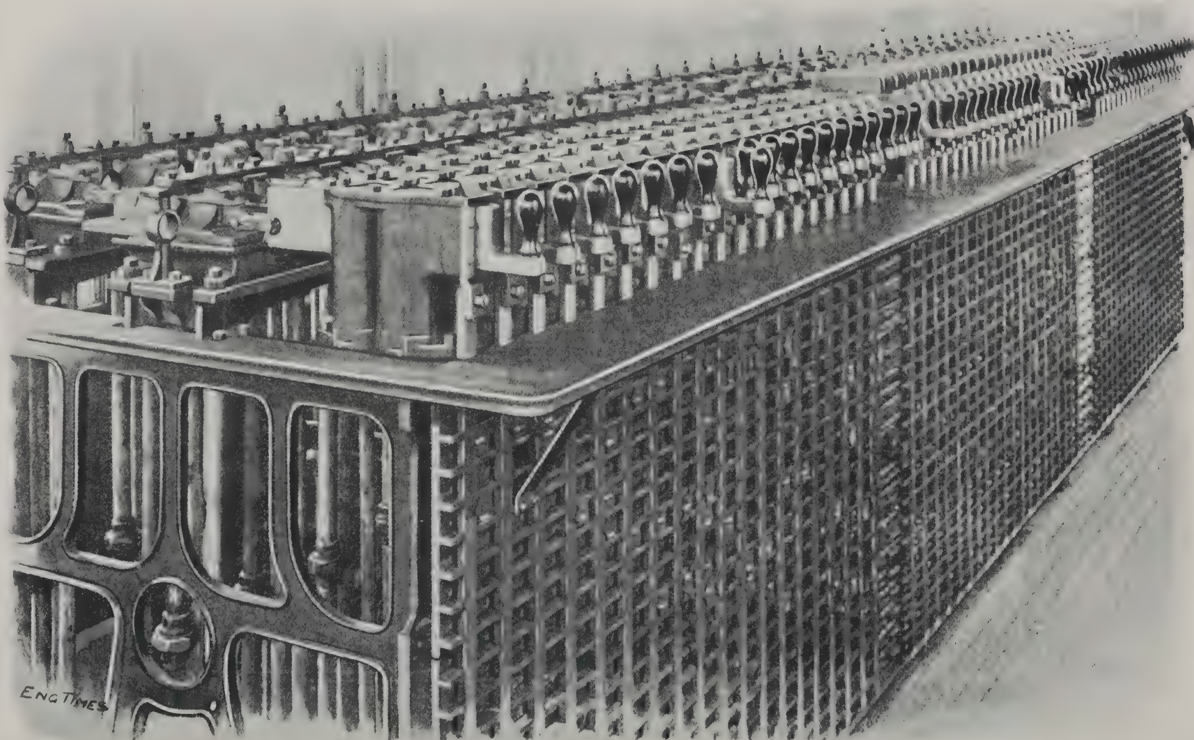
including all stops. For regular high speed traffic the Empire State express over the New York Central & Hudson River Railroad is a fine example of long distance running. The distance is 440 miles, and the running time, exclusive of stops, 8 hours and 9 minutes, giving an average speed of 50·18 miles an hour while the train is in motion. This also includes two stops for which no allowance has been made.

Another notable run is that of the Philadelphia & Reading Railroad from Camden to Atlantic City, a distance of 55·5 miles, that has been made in 47 minutes, or at a rate of 70·8 miles per hour. As an example of very fast running: when this train was first put on the schedule speed for the first 50 miles was made so fast that the engine could not possibly make it. An allowance of fifteen minutes was then made for the balance of the run, which enabled the train to arrive at the terminal on time. The engineer was then instructed to make time if he could, and a man with a stop watch was put upon the locomotive to report results. The schedule was kept in operation for ten days, with the result that for six consecutive days on one stretch of twenty consecutive miles, every mile was covered in less than 48 seconds, or faster than 75 miles an hour.

This is for regular running, but fast spurts are quite common. For a comparatively long distance the record is, I believe, held by the Lake Shore and Michigan Southern Railway, where a run of 86 miles was made in 70 minutes and 46 seconds, or 72·91 miles per hour, by a ten-wheeled engine hauling a train weighing 304,500 lb. Single miles are frequently covered at exceptionally high speeds. A mile in 45 seconds is not uncommon on the line between New York and Philadelphia, while the record stands at 38 seconds. The fastest time is, however, claimed for a New York Central & Hudson River engine, that covered a mile in 32 seconds, or something more than 112 miles an hour.

Such, then, in brief, are the steps that have been followed, and the final results that have been achieved, both in the service rendered and the mechanical construction of the locomotive engine as exemplified by American practice.

Geo. L. Fowler



LOW PRESSURE PNEUMATIC INSTALLATION OF 176 LEVERS AT THE GRAND CENTRAL DEPÔT OF THE NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

POWER INTERLOCKING AND THE LOW PRESSURE PNEUMATIC SYSTEM.

By JOHN P. O'DONNELL, M.Inst.C.E., M.I.Mech.E.

THE subject of power interlocking, that is to say, the substitution of power to produce the movements of interlocked points and signals for the manual levers commonly in use, has been prominently before the railroads both in Europe and in the United States for a number of years.

Various systems have been devised for accomplishing the desired result, and have been put to practical use with more or less success.

Very strong reasons make the general introduction of such a system eminently desirable. The tendency of modern railroads is to increase the carrying capacity of their roads by speedier manipulation of the trains, and shorter intervals between train movements. This speed of manipulation, so far as stations—particularly terminal stations—are concerned, is dependent upon the rapidity with which the necessary point and signal movements can be executed with safety and certainty.

With a manually operated interlocking plant, the physical effort involved, which is frequently very great, will limit the speed of manipulation before any other consideration. If this physical effort is reduced to practically nothing, the speed of a cycle of movements can be greatly increased. The comparatively great distance through which a mechanical lever must be pulled to effect the switch or signal movement desired, also lessens the number of successive movements possible in a given time interval, and can be easily avoided in a power system.

Another circumstance which argues for the introduction of power plants is the resultant economy. In the manually operated interlocking plant, the operator's labour is very exacting, and he can handle only a comparatively small number of levers, so that a large cabin requires a large number of men in several shifts.

With the power plant, the number of levers handled by one man depends merely upon his watchfulness, and not upon physical strength. As a consequence, there can be a considerable reduction in the labour account, while safety is enhanced instead of being decreased. In order to keep the trains moving with regularity and despatch, and to avoid errors, it is necessary that the operator's attention and intelligence be always alive, which cannot be the case when he has to do hard manual labour which wears him out in a short time.

Considering the manual effort as a source of power, a further economy results from the fact that the absolute quantity of power used for the manipulation of the parts is much less in power interlocking than in manual. It must be remembered that, particularly in a large railroad station in which many of the points and signals are distant from the cabin,

but a small part of the power applied to the levers is transmitted to the points. The greater part is lost by friction and by the inertia of the transmitting organs, whose resistance is considerable. With a well-constructed power plant, furnishing power which can be transmitted to a distant point without appreciable loss, it takes no more actual power to move the distant switch than the near one. The power used is dependent merely upon the resistance of the points themselves.

This consideration, furthermore, makes it possible to concentrate two, or even three, cabins into one, while still observing the necessary requisites of safety and ease of manipulation. The expense of duplicating cabins can therefore be avoided.

Having recognised the utility of power interlocking, it becomes necessary to choose the kind of power which is to be employed.

The three classes of power transmission which are to be considered, are as follows:—

1. Electric transmission.
2. Hydraulic transmission.
3. Pneumatic transmission.

The first of these three classes, that is to say, electric power transmission, would appear to be the most desirable, as it is at the present time very widely used, especially on the Continent, and electric power can easily be transmitted to any required distance. But the general requirements of railroad work must be taken into consideration. Electrical apparatus is necessarily complicated, fragile, and easily disturbed by outside influences. Simplicity and rigidity of the apparatus is essential to the satisfactory operation of any mechanical equipment on a railroad.

The electrical motors which form the typical moving elements of electric power transmission have a high speed rotary motion, whereas the movements of the points and signals must be rectilinear, gradual, and without shock.

Gearing must therefore be interposed, which will use much power by friction and by the effort of starting and stopping; the time consumed in starting and stopping will increase the interval between successive movements, and therefore prevent the rapid handling of the traffic.

Another important point to be considered in connection with electric power is the fact that in every railroad yard a great many electric conductors are used for other purposes than the signalling plant, and must be placed in proximity to the electric transmissions for the points and signals.

The danger of induction currents is, therefore, always present, and can hardly be avoided. Experience with electric plants has shown that signals have gone to safety and derails opened, causing accidents, merely through these induction currents. As safety is, of course, the prime requisite in any well-constructed apparatus of this nature, this fact alone may be considered sufficient to condemn the use of electric power. Everything must be so arranged that any failure of the plant or error on the part of the operator cannot possibly sanction an unauthorised movement of the train, or cause an involuntary switch movement.

All the above-mentioned evil features are present in the well-known Siemens and Halske system, used to some extent on the Continent, as well as in the more recent experiments of the London and North Western Railway at Crewe, which latter closely follow the lines of the German system, and, as far as can be gathered, show no improvement over it.

The maintenance also of an electric plant is considerably greater than that of an all pneumatic plant, for although the maintenance of the source of power may be taken, for the sake of argument, as the same in each case, the operative parts in the former for transmitting movements to the switches and signals are more delicate, require greater care on the part of the repair men, and also, as above stated, the liability to derangement is much greater. Even the present mechanical (rod and wire) signalling is much less expensive in maintenance than the electric system, although it is much more expensive than an all air system.

Under the four heads, therefore, of (1) rapidity in train movements, (2) safety, (3) maintenance, (4) initial cost, the all electric system must fail in its bid for the support of the railroads.

As regards hydraulic transmission, two main objections may be formulated.

In the first place, it has been found necessary to work at the excessive pressure of 750 lb. per square inch (50 atmospheres) in order to obtain the necessary speed. As a consequence, very heavy tubing must be employed to resist the strain, and any defective part of this tubing will cause it to burst and the water under high pressure to escape and do serious damage. The cost of such tubing is very considerable. The only hydraulic system (the Bianchi system) which has been used to any extent, necessitates heavy drawn copper tubing; this tubing is only carried to a certain distance beyond the cabin, and after the cost runs up too high, transmission to a greater distance is done by mechanical means (rod and wire connections), thus doing away with some of the chief advantages of power plants.

Hydraulic transmission has been found in practice to be very slow. In consequence of the high pressure, the friction against the inner walls of the tubes is very great and causes considerable retardation. It is well known that this retardation will increase more rapidly as the pressure increases.

The second objection to hydraulic transmission is found in the danger of freezing of the water, thereby destroying the utility of the power plant and damaging all the apparatus.

It has been attempted to avoid this danger to a certain extent by adding glycerine to the water, but, besides

FRANK L. DODGSON.

Inventor of the Low Pressure Pneumatic System of Power-Signalling. Born in New York State in 1866. Graduated at Cornell University in 1889. Afterwards practised as consulting engineer on hydraulic and railway work in Rochester and the West.

being costly, experience has shown that this remedy is not infallible. In very severe weather, the glycerine will separate from the water, and ice formation will take place. On the Moscow Kazan railroad in Russia, the Bianchi system was experimentally introduced, but the mixture of water and glycerine froze frequently, and the only manner in which the plant could be kept partially in service was by using petroleum.

Again under the four heads, (1) rapidity of train movements, (2) safety, (3) maintenance, (4) initial cost, the all hydraulic

system must fail in its appeal to railroads, as indeed it has failed; for it has been before the railroads of Great Britain for more than ten years, under the auspices of an eminent firm of signalling engineers, Messrs. Saxby and Farmer, Limited, with the result that no railway company in Great Britain has ever used this system in regular serious service. I say serious, because no doubt it will be said that Messrs. Saxby and Farmer are about to put down a plant somewhere, or have one in experimental use, or used in some duty not exactly applicable to railroads, such as the Tower Bridge plant.

There is also a type of apparatus in which one kind of power is used for transmission and another kind for actuating the switch or signal movements. Such systems are:—The electro-pneumatic and the hydro-pneumatic.

It is quite evident that these systems have most of the disadvantages of electric and hydraulic transmission, and are open to other objections besides. For instance, there must be two sources of power to furnish the two kinds of power required, and as each of these power sources requires separate care and attention, maintenance becomes costly and complicated.

The representative system on this principle is the Westinghouse electro-pneumatic. In this apparatus, the working of the points and signals is done by compressed air supplied from a main, but the valves admitting air pressure to the working cylinders are opened by an electric current transmitted from the cabin levers. The strength of the electro-magnets opening these valves is necessarily limited, and consequently the valves must be very small and the construction extremely delicate and liable to derangement. The valve openings must be small to correspond with these valves and also to avoid shocks, so that a comparatively high air pressure is required, and all the dangers of leaks and condensation are present. These small openings are easily obstructed by any small particles carried by the air. The danger of unauthorised movements through induction currents is as great in this system as in the all electric devices.

The rules of the Railroad and Commerce Commission of the State of Illinois more nearly approximate the English Board of Trade Rules than any other State in the Union. These rules enforce one of two things, viz., either derails wherever one road crosses or intersects another, or, failing derails, all trains must be stopped before passing over the intersecting point.

The Stewart Avenue plant at Chicago is worked on the electro-pneumatic system; and the officials in charge rather than put in derails stop all trains at the intersecting point, therefore there are no through trains at this plant. This would appear to be a serious disadvantage in the electro-pneumatic system.

In the *Railway and Engineering Review* of March 16th there is an illustration, with a fairly accurate description, of the arrangement of switches and signals operated from Towers A and B, Sixteenth Street Subway, Chicago and Western Indiana Railroad (see plans of roads, Figs. 1 and 2), which handles the same traffic as the Stewart Avenue plant above referred to, being only half a mile away from this plant. In this plant (Sixteenth Street Subway) derails have been inserted in accordance with the rules of the State, and permission has been given by the State to run trains through without stopping. The officials in charge of this place, deeming that the low pressure pneumatic system of handling derails afforded, according to their views, sufficient safety, have therefore sanctioned the running of through traffic, and trains of the following railroads enter Dearborn Street station over this

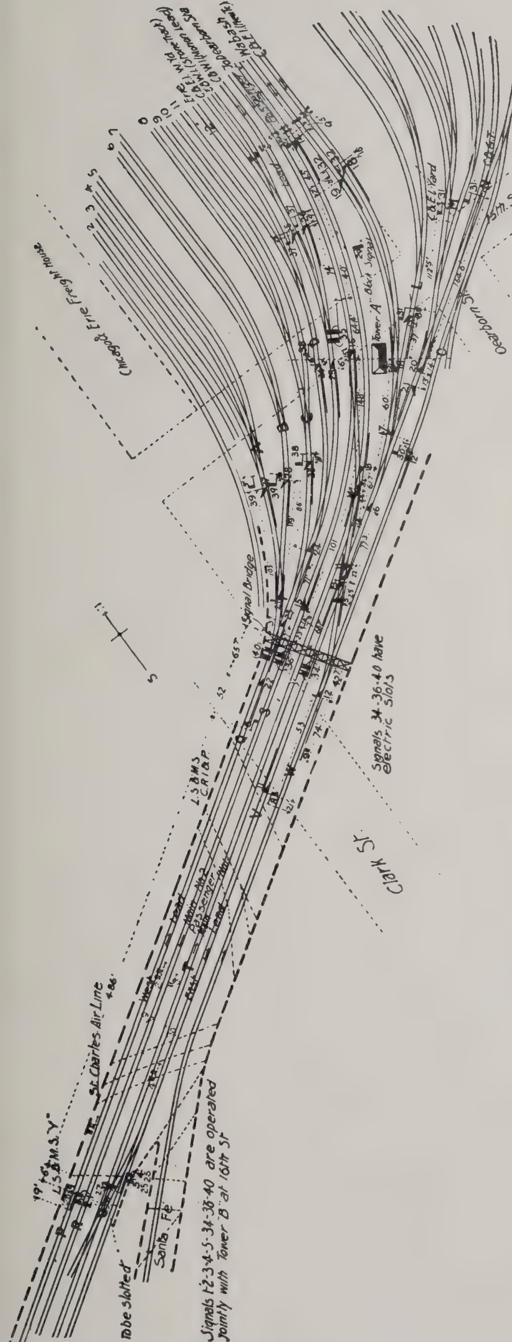


FIG. 1.—SHOWING ARRANGEMENT OF SWITCHES AND SIGNALS OPERATED FROM TOWER "A."

FIG. 2.—SHOWING ARRANGEMENT OF SIGNALS AND SWITCHES OPERATED FROM TOWER "B."

plant:—Chicago and Eastern Illinois Railroad, Wabash Railroad (two divisions), Chicago and Eerie Railroad, Chicago and Grand Trunk Railroad, Chicago, Indianapolis and Louisville Railroad, and the Aitchison, Topeka and Santa Fe Railroad, each and all of these railroads carrying a big suburban traffic as well as their main line traffic. There is a tunnel a quarter of a mile long, which is governed by track circuit, between the two towers A and B. The signalling arrangements at this place allow of a train every 30 seconds through the tunnel.

In all of the principal systems hereinbefore described, there is a distinct break or time interval in each lever operation, which necessitates the signalman remaining at the switch operating lever until the indication has returned to the cabin, and to then complete its final motion before he can proceed to operate the correlated signal lever. This alone is fatal in any up-to-date system, for, as I have stated before, the first essential is rapidity in moving the operating levers, rapid transmission of power to the objects to be moved, and by these rapid results quicker train movements, the track of railroad governed by the signalman yielding better results to the railway company.

In considering the all pneumatic transmission, it will be found to have none of the disadvantages mentioned in connection with the other systems.

The apparatus can be simple and strong; there is no danger of freezing or of leakage at low pressure; an essential to successful pneumatic operation of switches and signals is the use of air at low pressure, for reasons which will be pointed out in connection with the following description of a low pressure pneumatic interlocking apparatus, extensively used in the United States, and now being introduced into Great Britain by the British Pneumatic Railway Signal Company, of which the writer is chairman.

As a pioneer in railway signalling to some small extent—having built up one of the largest, if not the largest, works for the manufacture of railway signalling appliances in Great Britain—I have been looking out for some seven or eight years for a power system of signalling that I could confidently recommend to the railroads, embracing the four essential elements already set forth herein, and to these must be added that comparative rough and readiness (absence of delicate parts and scientific knowledge) necessary in any mechanism required to be fixed to the road bed of a railway, subject to the climatic conditions of this country, and to the class of repair men generally employed.

I made personal examinations of the several signalling systems in the United States last autumn, and I was fortified in my opinion that the all air low pressure system was the only one likely to appeal with success to the British railroads, by the fact that, with one single exception, I believe all the power system contracts given out in the United States during the last two years were awarded to the Pneumatic Railway Signal Company of Rochester, the owners of the low pressure system. My opinions and statements are open to the criticism of the promoters of the other power systems. I invite criticism. It is time the railroads of this country took a deeper interest in power signalling, for it is only by a reduction in fixed charges and getting a greater use out of their existing lines that they can keep up with the increased labour bills and price of materials. I therefore make no apology in appealing to the railroads, for I know too well that any system not to their advantage has no chance, and for any system that is to their advantage, as I am convinced the low pressure

system is, they will require no persuasion from me to adopt it.

The low pressure system is not the system of a railway company. It is the product of private invention, namely, that of Mr. F. L. Dodgson, of Rochester, New York, U.S.A., loyally supported and entirely financed by private individuals who have spent their money willingly and confidently for the last five years. They stood to lose if it turned out a failure; they stand to gain now it has turned out a great success.

The whole manufacture of the parts necessary for this system is now taking place at Messrs. Evans, O'Donnell & Co.'s works at Chippenham, by British labour, British capital, and British machinery. Those who introduce fresh industries to this country, who try to bring here up-to-date methods, who use their best endeavours to keep up sides with our foreign rivals, whose enterprise helps to support the railroads, surely ought to get some reciprocity from the railroads in return! It is with this end in view that I appeal to those large railroads who do all their own mechanical signalling to put the low pressure system to a thorough comparative test with the present system of mechanical signalling, feeling confident that the results, which

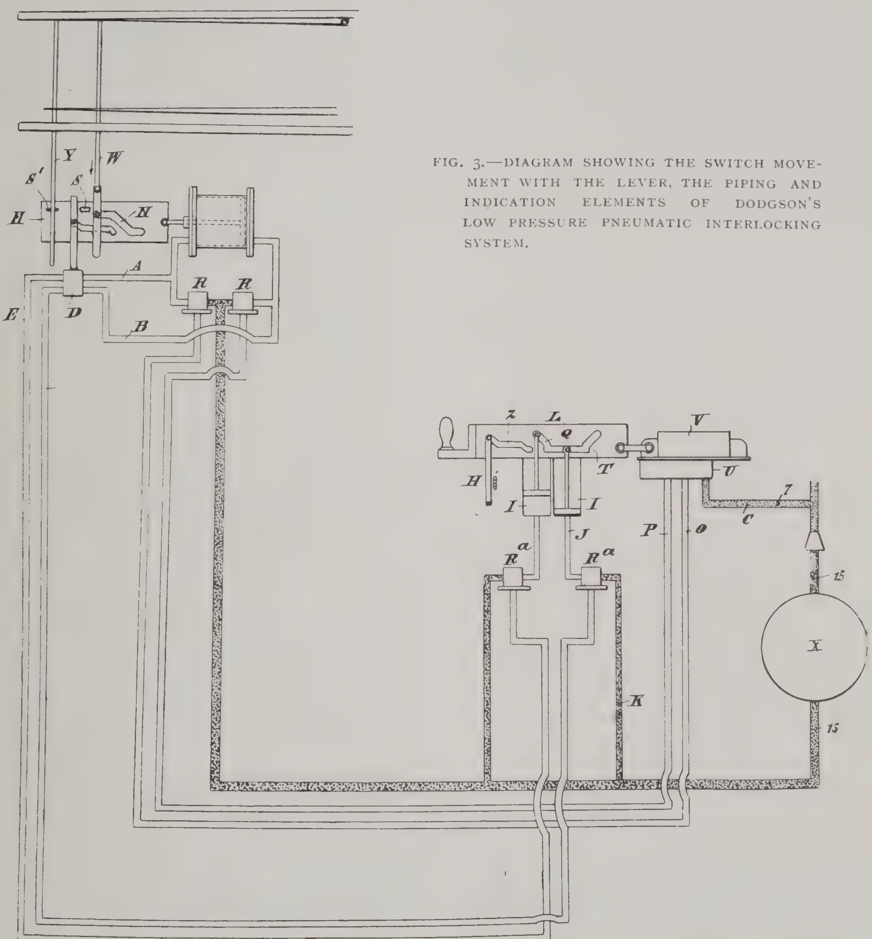


FIG. 3.—DIAGRAM SHOWING THE SWITCH MOVEMENT WITH THE LEVER, THE PIPING AND INDICATION ELEMENTS OF DODGSON'S LOW PRESSURE PNEUMATIC INTERLOCKING SYSTEM.

I have hereinbefore stated should be considered as essential to any system of signalling, manual or power, will be found to have been fulfilled in the low pressure system.

The apparatus to be described is an all pneumatic device; there is but one power—that furnished by compressed air, and all the movements are accomplished by this single force, the apparatus being constructed in such a manner that the most exacting requirements as to safety, simplicity and durability may be satisfied. The results are primarily obtained by using the air at a very low pressure—only 15 lb. per square inch. The great advantage resulting from this low pressure will be easily recognised by an examination of the construction and operation.

Figs. 3 and 4 show diagrammatically, first, the switch movement with the lever, the piping and the indication elements; secondly, these same parts of a signal movement. The air tank is indicated by the letter X: it is fed by a compressor, which may be located at any convenient point. Before passing into the tank, the air goes through a coil which forms a drying apparatus, and the pressure, which is usually higher in the compressor, is reduced by a reducing valve placed in the supply pipe leading from the compressor to the tank. From this tank a main supply pipe is carried the entire length of the yard, with branch lines leading to the valves R of every signal and every switch. This main supply pipe, with its branches up to the valves, is normally always filled with air under pressure. The machine in the cabin has a set of sliding plates, L, provided with a handle, which are called "levers" by analogy with a mechanical system. The levers are connected to slide valves V, sliding on their seats U. The interlocking is done by the locking bars H in a manner

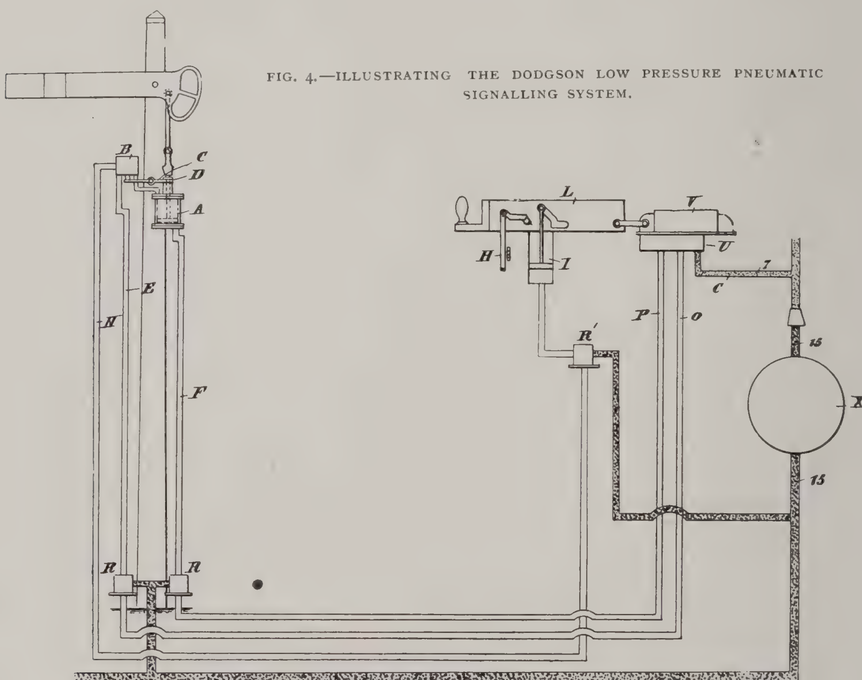


FIG. 4.—ILLUSTRATING THE DODGSON LOW PRESSURE PNEUMATIC SIGNALLING SYSTEM.

which will be explained further on. Compressed air can enter the supply ports of the valve seats by a pipe coming from the tank. It must be

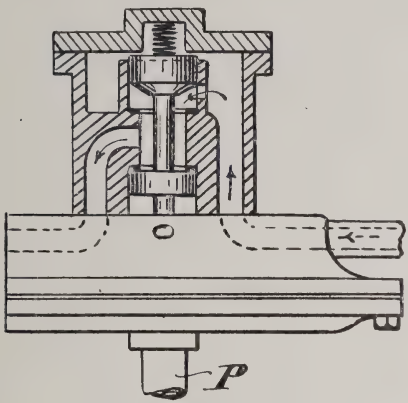


FIG. 5.

noted, however, that there is a further reduction of pressure by means of a reducing valve placed in the pipe leading to the valve seats; that is to say, that the air which is distributed by the slide valves of the machine has a pressure of only 7 lb., or one-half the pressure in the main line. Two pressures are therefore needed: a pressure of 15 lb. per square inch which is used to move the switches and signals, and a pressure of 7 lb. which is only used for transmission in the following manner:—The slide valve is so constructed that in two of its positions a port in the valve opens communication between the supply pipe of the machine and one or the other of two pipes O and P, whereas in all other positions of this valve these two pipes are connected to the atmosphere through the exhaust ports of the valve. The pipes O and P end underneath the diaphragms of the valves R at the switch. At these points, R R, are placed diaphragm valves, which are called "relay valves," and whose construction is shown by Figs. 3 and 4. The valve is opened by pressure upon the diaphragm, which lifts against the resistance of a spring, thus establishing communication through the ports shown between the entrance and exit ports. The air coming from the main line always fills the entrance port of the valve, ready to enter the cylinder by the exit port as soon as the valve has been lifted.

Fig. 5 shows the valve opened so as to admit air from the supply to the outlet leading into the cylinder. Fig. 6 is a section in a plane at right angles to Fig. 5, showing the valve closed, the supply cut off, and the cylinder open to exhaust to the atmosphere through the exhaust ports e^x e^x.

It will be noticed that the lever has two slots, Q and U, of the contour shown. Below each lever are two cylinders, I I. The rods of the pistons sliding in these cylinders carry rollers which are guided in the slot Q. The locking bar H also carries a roller at its upper extremity, guided in the slot U. Let us suppose that a movement is to take place. The operator will first pull the lever out until the roller on the piston abuts against the shoulder T of the slot, thus limiting the outward movement for the present. By this

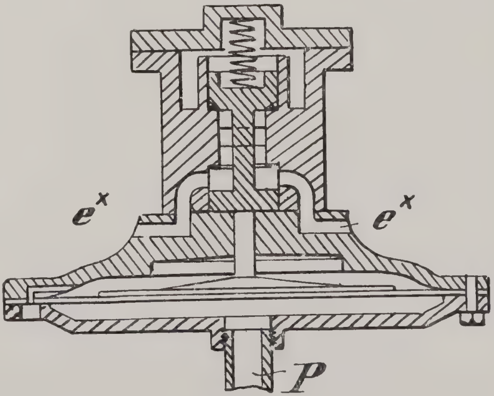


FIG. 6.

movement the slide valve has been placed into such a position that it opens a passage, through its port and the ports of the valve seat, between the pipe C

and the pipe P. At the same time, because of the shape of the slot U, the locking bar has completed one-half only of its vertical movement, in such a manner that the interlocked levers, which were free in the original position of the switch, are now locked, whereas those which correspond to the reversed position of the switch are not yet free. This can be followed out by examining the diagram of the locking plate shown in Fig. 7. The pipe P ends underneath the diaphragm of the valve R. Consequently, as soon as air can enter and fill

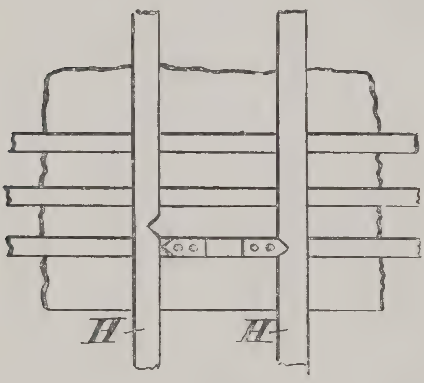


FIG. 7.

this pipe, the valve will be opened by the pressure exerted upon the diaphragm. Communication is thus established between the air in the main supply, or in the branch leading to the switch and the switch cylinder, and the piston of this cylinder is moved. The rod of this piston is directly attached to the switch motion plate M. This plate has two slots, N and N′, and the two projections S and S′. These projections lock the switch in its two extreme positions by means of a lock bar, Y, fixed to the switch, and having notches to receive the projections.

The switch bar W carries at its extremity a roller guided in the slot N. This slot N has two parts parallel to the axis of the cylinder united by a diagonal part. Another slot N′ in the motion plate has two extreme inclined parts united by a part parallel to the cylinder axis. The indication slide valve D is moved by this slot by means of a connecting rod and a roller guided in the slot. In the position of the parts shown in the diagram, this slide valve is so placed that its port forms a communication between the pipe A, which unites with the passage leading from the diaphragm valve into the cylinder, and a pipe E which returns to the machine. In the other extreme position of the indication valve, communication will be established between the pipes F and B in the same manner. As soon as the piston begins to move forward, the indication valve will be moved to its middle position by the incline of the slot, so that all communication between these pipes is shut off. At the same time the switch will be unlocked, as the projection S′ will move out of the notch in the lock bar B. This first part of the piston movement will have no effect upon the switch, as the roller on the switch bar will be simply guided in the parallel part of the slot N. This part of the movement is also utilised to start the detector bar, which is connected to the motion plate by rods and a lever. As soon as the switch has been unlocked, the continued movement of the piston will move the switch over by means of the diagonal part of the slot N and the switch bar. During this time the indication valve will remain stationary. After the switch has been entirely reversed, the projection S′ will enter another notch in lock bar Y, and the moving and locking of the switch will have been accomplished. The last part of the stroke of the piston will now move the indication valve to its extreme position, so that a communication will be established between the pipes B and F. As the diaphragm valve (relay valve) remains open, air will therefore enter the pipe F

from the pipe B through the indication valve. This pipe F, as above stated, returns to the machine, and ends under the diaphragm of another relay valve R *a*, precisely similar in construction to the one already described. The air pressure through F will open this valve and establish communication between a branch K of the main supply and a pipe J which leads into the cylinder I. It will be remembered that all these movements have taken place because of the pulling out of the lever to the extent limited by the roller on the piston of the cylinder I. When air now enters under this piston, the roller will be lifted clear of the shoulder H, will enter the diagonal portion of the slot in the lever, and, by the continued action of the upward pressure, will push this lever out still further until its stroke is completed and the roller abuts against the end of the slot. This complementary part of the stroke of the lever is accomplished automatically, that is to say, the operator is not obliged to wait for the indication to return to the machine before he grasps the following lever, but he can immediately place his hand on this lever, which will be freed as soon as the indication will have completed the stroke of the first one. It will be seen that the movement of the interlocking bar H is completed by the indication stroke through the inclined part of the slot Z. The machine valve V will be in its extreme position in which its exhaust port will connect the pipe P with the atmosphere. The air under pressure which filled this pipe, and held the relay valve R open, will therefore exhaust, and the spring of the relay valve will close it, shutting off the main supply and opening an exhaust passage through which the air in the cylinder can escape. All parts will again be in a normal position of rest, in which all the pipes, except the main supply and the supply to the machine, are open to the atmosphere and are subjected to no pressure. In order to move the switch back to its original position, the operation is precisely the same, only the other cylinder I and the other relays R and R *a* will be in action as well as the corresponding set of operating pipes.

It will be seen that the indication—that is to say, the return of air to the machine in order to complete the stroke of the lever and of the interlocking bar —is imperative as well as automatic. If from any cause whatever the switch has not moved over completely, or has not been locked in position, the indication valve will not establish the communication above described, no indication will be received in the cabin, and the levers interlocked with this switch lever cannot be pulled, so that no signal can be lowered and no conflicting switch moved.

In order to operate the signals, the construction is similar to that of the points, with the exception that the indication, which, in the points, must be given for both positions, is only given for the normal or danger position of the signals. There is again a lever similar to the switch lever, and a slide valve which allows air to enter one or the other of two pipes O and P. The pipe O leads to the relay valve R, and, opening it, allows air from the main supply to enter into a pipe F, which leads below the piston of the signal cylinder A, pushing the signal to safety. The roller of the cylinder I limits the stroke of the lever, and there is no indication. In resetting the signal to danger, it is necessary to have an indication in order to be assured of the fact that the signal has again reached its horizontal position. Instead of having an indication slide valve as in the switch movement, the indication valve in this case is a valve constructed

precisely like the relay valves, actuated, however, by a lever C, whose extremity abuts against the valve stem, instead of by a diaphragm. When the signal is in its normal or danger position, as shown in the diagram, this indication valve is open, thus establishing communication between the pipes E and N. As soon as the signal goes down to safety, the collar D on the piston rod, which abuts against the extremity of the lever and keeps the valve open, will move away from this lever, and the spring of the valve will close it in such a manner as to shut off the passageway between the pipes N and E. In order to bring the signal back to normal, the lever is pushed in until the roller at the extremity of the piston abuts against the shoulder of the slot. As has been explained in describing the switch movement, this lever movement again allows air from the supply X to enter the pipe O. The relay valve R will be opened, and main supply air will enter the top of the cylinder above the piston, pushing down the latter and resetting the signal. It will be noticed that the pipe E leads to the indication valve B, but as this valve is closed when the movement begins, air cannot enter the pipe N. As soon as the signal has again reached its horizontal position, however, the collar D will abut against the lever, opening the valve E and sending air through the pipe N to the relay R′ of the machine, opening the latter and through it admitting pressure to the cylinder I, whose piston and roller complete the movement of the lever in the manner heretofore described.

It will be seen that, as in the switch movement, if the signal does not go back to danger from any cause whatever, no indication will be given, and the interlocking on the machine will prevent conflicting lever movements.

This description of the operation of the apparatus shows that it fulfils the most exacting requirements as to absolute safety. It is impossible to move a switch or a signal if any of the other organs corresponding to it are not in the correct position. Any derangement of the switches or signals which would prevent regular operation is immediately indicated in the cabin by the fact that the lever does not complete its stroke. It is easy to see that this means of operation can be adapted to any already existing switch or signal construction without any difficulty. It must be noted that, primarily, the system presents an apparatus of movement and control, that is to say, that a rectilinear reciprocating motion is given to a rod placed near a switch or near a signal, and an air current is sent back to the machine in order to give an indication if the desired switch or signal movement has actually taken place. It is evident that the constructions by which the movement of the rod is transmitted to the switch or signal can be varied at will. The transmitting devices shown are, it is true, a part of the construction, but it is always a secondary and independent part. If it is desired, this rod may be applied to already existing switch and signal movements, provided the indication elements are preserved. In this manner trailing points or signals turning on a vertical axis present no difficulties.

The use of air at the low pressure of 15 lb. per square inch presents many advantages. Ordinary gas-pipe and ordinary joints may be used without danger of bursting or leakage. The amount of condensation which might occur is much less than with high pressure, and experience shows that it is an entirely negligible quantity. Because of the low pressure, all openings are large in section, so that there is no danger of clogging the passageways. All the organs—the cylinders,

valves, the mechanical parts in short—are quite large and very strong, and can consequently easily resist the effects of the vibrations given by passing trains. All the pipes, with the only exception of the main supply and of the supply of 7 lb. pressure, supplying air to the machine, are normally open to the atmosphere when there is no movement, and any dirt, or even water, which may be carried along by the air, can freely escape.

Another important advantage resulting from the low pressure is found in the fact that, should the switch movements temporarily work harder because of reconstruction of the road bed or settling of the tracks, the pressure can be increased, or even doubled for the time being, without danger of leaks or bursting. Apparatus and pipes which can stand 15 lb. pressure can easily stand 30 lb. if necessary, whereas, if the ordinary working pressure is 75 or 90 lb., it cannot be much increased without danger.

The speed of response of the switch or signal to the lever movement is almost as great as would be that of electrical transmission at a mean distance. Experience has shown that a switch 500 ft. from the cabin can be moved and the indication received back in the cabin within two seconds from the moment the lever is pulled.

Inspection of the construction will show that the durability of the apparatus is very great. The transmitting parts, whose proper repair and renewal is the most expensive part of a mechanical plant, are simple pipes buried in the ground, in this system, and they will last as long as ordinary gas-pipe used for conveying gas, as they are not subjected to any pressure high enough to destroy or weaken them. The mechanical parts can be very rigidly constructed, and are subjected to but little wear. Experience with this system in the yard at Buffalo, N.Y., where it has been in use since February 1st, 1898, without a single stoppage, may show the economy of working. The cost of repairs has up to the present time amounted to but $3.85. As the apparatus has been in service during two hard winters without any derangement by frost, it follows that the question of condensation has been effectively solved.

It is easy to show the economy resulting from the use of this system. Besides the saving in inspectors and repair men, who are not nearly so numerous as in stations where mechanical apparatus is in use (one inspector is sufficient for the largest yard), the number of tower-men may be materially reduced. In the Grand Central Station at New York, where one of these installations having 176 levers is in service, it was necessary, before the introduction of the pneumatic system, to have two mechanical towers of 100 levers each. The possibility of concentrating all the levers in one cabin resulted from the use of the pneumatic system. In these two cabins the number of lever movements in a day of twenty-four hours was 21,115. In order to accomplish this number of lever movements, twenty-three tower-men, in three shifts of eight hours each, were needed. With the pneumatic system eight men only are required. The New York Central Railroad, which owns this station, estimates a saving of $12,000 a year, resulting from the adoption of pneumatic signalling.

In point of speed, as illustrating the facilities afforded by the low pressure system, the Pneumatic Railway Signal Company have installed their low pressure system on the Philadelphia and Reading Railroad, under guarantee of providing for a train every thirty seconds, the farthest switch in this plant being 500 yards from the tower, and at this distant point from the signal cabin a

train has to be received and handled every thirty seconds.

By comparison with a mechanical plant, it may be said that the first cost will not be more than 50 per cent. to 70 per cent. higher. The cost of power and maintenance together is less than that of maintenance of a mechanical plant alone under average conditions.

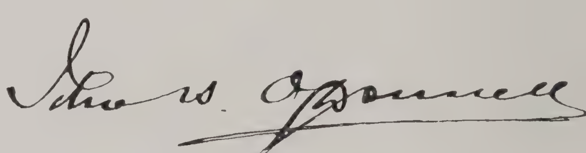
The following figures are appended in order to give an idea of the dimensions :—

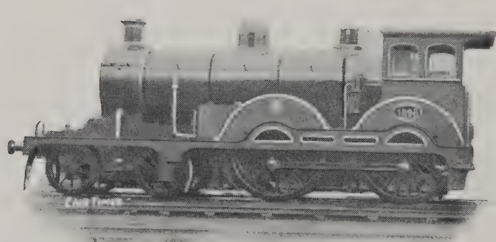
The diameter of the switch cylinder is ten inches ; that of the signal cylinders is five inches. The main supply pipe consists of two-inch pipe at its origin, and the diameter of the pipe diminishes towards the end of the yard. The operating and indicating pipes are all one-half inch. The branches from the main supply to the relays are three-quarter inch pipes. The distance between the levers centre to centre of handles is three inches.

The quantity of air employed is very small. For a cabin of 100 levers, under average conditions, the compressor should have a capacity of 100 ft. of free air per minute. This capacity is governed, not by the number of levers in the cabin, but by the maximum number of train movements occurring in a given time.

In comparison with a mechanical system, levers can be saved by a system of selection of signals. One lever may operate two signals which correspond to the two positions of a certain switch. This is accomplished by a selector, that is to say, a slide valve, and which has a port forming a passage between a single pipe coming from the machine, and either one or the other of two pipes leading to the two signals. In a similar manner a series of switches, whose movements always follow each other, may be united to one lever. The indication valve from the first switch, instead of sending air to the machine, sends it to the next switch to operate it, and so on until the last switch of the series sends the indication to the cabin.

This article deals only with the interlocking systems. A logical continuation of such a system is the automatic block, which completes the signalling of a road, and thus provides ideal conditions for safe and rapid traffic handling, and the working of a road up to its full capacity. Block signalling will be discussed in a future paper.





DESIRABILITY OF TRAMWAY SECURITIES AS INVESTMENTS.

By J. G. WHITE.

AS a class, tramway securities are comparatively new to many investors. It is only within the last ten years that the development of mechanical traction for tramways has enormously increased their importance, and removed them from the class of enterprises conducted largely by individuals to that conducted by limited companies, with securities quoted on the exchanges. In America, perhaps more than in England, due to the greater tramway development, securities in these companies are recognised as amongst the safest and most desirable investments, and their market values are ordinarily based on nearly the same interest rates as are the securities of steam railroads.

There are really two classes of investors who are likely to be interested in tramway securities, and these we might call the permanent investor and the speculative investor respectively.

The former class comprises those who wish to find an investment for a term of years, who wish to avoid risks, and who are satisfied with a thoroughly safe investment which will pay 4 or perhaps 5 per cent. interest. The second includes those who wish to make a larger return on their capital, say from 6 to 25 per cent. per annum, and who are willing to take the slight risk incident to building a new tramway, under good franchise and other conditions, or buying and electrically equipping a horse tramway.

Both classes of investors should study carefully the factors determining the values of the respective properties; these factors being, of course, much more difficult to judge where properties have not yet been electrically equipped. In either case, and especially the second, the prospective investor should have the advice of competent tramway engineers—engineers who know not only the technical, but also the commercial or business side of their profession.

Many tramway engineers and officials have some general rule that tramways should be able to operate for some set percentage of their gross receipts—say, 60 per cent. The fallacy of such calculations is only too plainly shown by the enormous shrinkage in the prices of tramway shares which has taken place during the past year in Belgium, Germany, and France.

In ordinary American cities the fares received average between two and two and one half pence (2*d.* to 2½*d.*) and the cost of carrying each passenger between one and a quarter and one and a half pence (1¼*d.* to 1½*d.*). It seems incredible that with fares about half as high as in America, presumably competent engineers should estimate that operating expenses should decrease in proportion, in spite of higher cost of fuel and slower speeds of cars, the latter offsetting the lower wages prevailing in Europe.

On the contrary, the average cost of operation per car mile is practically the same in Europe and America.

The more this general subject is

studied, the more apparent does it become that no one, two, or even three actors determine the earning capacity of any tramway. In fact, in valuing any tramway all the points in the following table should be carefully studied and each given its proper weight for the individual case.

Chief factors determining the value of a tramway.

(1) Franchise.
- (*a*) Duration.
- (*b*) Exclusiveness and possible increases in competition.
- (*c*) Terms of surrender of property at expiration.
- (*d*) Fare limitations.
- (*e*) Speed limitations.
- (*f*) Special conditions.
- (*g*) Taxation, construction necessary, paving required, etc.

(2) Capitalization.
- (*a*) Method of finance—Proportion debentures and shares.
- (*b*) Relation to probable cost and to net earnings.
- (*c*) Fixed charges, sinking funds, depreciation, amortization.

(3) Plant.
- (*a*) Cost and value.
- (*b*) Efficiency commercially.

(4) Earnings—Governing conditions.
- (*a*) Actual results or probable future results on new or reorganised lines.
- (*b*) Rates of fare.
- (*c*) Population.
- (*d*) Distribution of population.
- (*e*) Length of Lines—Average haul.
- (*f*) Character of service :—
  1. Amount or frequency.
  2. Speed.
  3. Cars, size and type.
  4. Stopping places.
- (*g*) Riding factor governed by :—
  1. Character of population.
  2. Race.
  3. Climate.
  4. Average income.
  5. Occupation.
  6. Amusements available.

(5) Operating expenses.
- (*a*) Analysis and comparison of expenses and accounts.
- (*b*) Expenses affected by :—
  1. Labour cost.
  2. Permissible speed of cars.
  3. Size of tramway.
  4. Cost of fuel.
  5. Character of construction (maintenance).

(6) Net earnings.
- (*a*) Count book-keeping, no operating charges being made against capital account.
- (*b*) Fixed charges.
- (*c*) Depreciation charges and amortization of franchise.
- (*d*) Future probabilities with growth of city, etc.

After having collected all available data on all the points mentioned in the preceding table, there remains the task of assigning to each item its proper relative value. This requires such special skill as comes only from long experience in this particular field of tramway work, and requires an analytical mind specially fitted for weighing mentally many conditions which cannot always have assigned to each a definite value. The more obvious of the reasons fixing the values of the various points are outlined in the following pages.

FRANCHISES.

Duration determines the amortization fund required to repay the capital expended, and fixes also the period during which a surplus profit above such amortization may be realised by the proprietors.

The terms of surrender naturally fix the probable sale value at the end of the concession, and the importance of these terms is evident, as is also having a

franchise which is exclusive either by stipulation of concession or by natural conditions.

The importance of *fare limitations* seems, however, not to be at all appreciated on this side of the Atlantic.

In America the competition between different groups wishing to build tramways has usually taken the form of building parallel lines, while in Europe this competition has resulted in the accepting, by the financiers interested, of franchise conditions so onerous that in many instances the tramways built under these concessions can never pay.

While this competition has been confined largely to the Continent, there is an evident tendency in the same direction in Great Britain and in the British colonies, particularly Australia.

Another really important portion of a concession is that relating to *speed limitations.*

Reasonably high speeds are necessary to encourage riding, and also to keep down operating expenses. The increased cost of power for any speed up to twenty miles per hour is of little importance. On the other hand, the wages of conductor and motorman for an hour will be the same whether their car travels six miles or sixteen. On a given line, therefore, more people will ride, and a specific frequency of service can be maintained more cheaply with high speed operation.

Special conditions affecting construction required, paving necessary, etc., are usually of importance as affecting both first cost of a line and charges to be made later, not only for interest, but for taxes and maintenance as well, and consequently should all have due consideration.

CAPITALIZATION.

The importance of this factor is generally known. It is difficult to fix any rule by which one can judge as to over-capitalization. A tramway may easily cost anywhere from £2,000 per mile for a cheap, light railway to £30,000 per mile for a conduit road in a large city where complicated and expensive special work is required, many pipes and obstructions have to be moved, many handsome cars are required, with proportionate power plant equipment, and where conditions generally contribute to a maximum cost.

Nevertheless, some general idea on this subject may be obtained from statistics showing the actual costs of generally similar roads in other cities having about the same conditions.

The relation of capitalization to net earnings is, however, much more important than that to first cost of installation.

After paying all operating costs, the earnings should fully provide for debenture interest, depreciation of plant, sinking fund to retire debentures, and amortization to repay capital during concession.

If after all these have been properly and fully met, there remains a reasonable dividend for the company's shares, we may ordinarily say the enterprise has not been over-capitalized. Tramway receipts are, however, seriously affected by business depression influencing local industries, so that net earnings in prosperous times should show a large surplus above all fixed charges.

The danger lies in not realising what is necessary to adequately provide for depreciation. Most tramways starting their electrical equipment have new cars, new power plant, new track or permanent way, and while depreciation progresses daily, it may not for some years reach a point which necessitates large direct expenditures.

The books of tramway companies are seldom falsified, while inadequate charges to maintenance are frequent even under the most conscientious management.

Usually, therefore, the protection of the investor requires less the chartered accountant than an intelligent engineer to advise as to the adequacy of the charges above mentioned.

PLANT.

The most important consideration in connection with the plant is that it shall be well adapted to its main purpose, viz., the encouraging of a maximum amount of riding by the tributary population, and the carrying of those who do ride at a minimum cost. While first cost of plant is important, it is within reasonable limits secondary to the efficiency of the plant for its intended purpose.

The limits of this article are too small to admit of even a general discussion of the engineering questions involved in deciding on the details of the best plant advisable for any given installation.

The size, type, and speed of engines, the size and type of boilers, system of condensing advisable, and all other similar points can be determined only by a careful study of the local conditions, including fuel and water supply available. In the same way the type of track or permanent way, the size, type and speed of cars, and all other like questions, are dependent solely on the local conditions, and can be determined only after a careful study of these. As to these details the ordinary investor will not have time to inform himself, and must rely largely on his engineers. He may, however, satisfy himself that his engineers are capable not only from a strictly technical point of view, but that they understand the importance of a judicious weighing of all the commercial considerations involved, so that the plant when completed will be such as will best serve the people living within the territory tributary to the lines, and that while the first cost of the plant is not excessive it shall operate with a maximum of economy, that its depreciation shall be slight, and that the service shall be regular and well adapted to the requirements, and that the total earnings of the property shall be as large as possible.

EARNINGS.

There are so many factors which contribute to determine the earnings of any property that no full discussion is possible within the scope of this article. With an operating property the actual present earnings may be taken as some guide to what may be expected with new plant and equipment or under new management. For a projected property, however, calculations as to probable earnings must be based solely on a study of local conditions.

Rates of fare.—One of the most important, and one which has received in many cases too little consideration, is the tariff or schedule of fares charged.

The fares should be so regulated as to foster and encourage riding, bringing the net earnings up to a maximum. Excessively high rates of fare will discourage riding, resulting in a decrease in the gross takings, while on the other hand, if rates of fare are too low the gross takings may be satisfactory, but the actual cost of carrying passengers may approximate the fares received so as to leave little or no margin for depreciation, interest, amortization and dividends. It is also important that the schedule of fares should be such as to permit of easy and prompt collections by the conductors, and in such form as to lead to a minimum of peculation on the part of the tramway employees. The numerous questions connected with the fares for different zones, the various classes into which passengers and fares should be divided, and other points of similar tenor, deserve most careful consideration.

Population.—Population is another important factor. Other considerations

being equal, the gross takings of a tramway will increase in a somewhat greater proportion than the tributary population. Other factors, such as *distribution of population*, *length of line*, *average haul*, *etc.*, are so important that the tributary population alone is no real index to earnings which may be expected.

With any given population the gross takings will be greater if the people live at some considerable distance from the centre of the town or city, and probably the highest earnings per capita will come from a given population distributed over a long narrow territory.

The above diagram shows curves indicating the minimum, maximum, and average gross takings per capita for American towns and cities of different sizes up to 200,000 population. These curves are based on a study of the actual results of some 200 tramways, and the curve showing the average receipts per capita is reasonably correct. An inspection of these curves will show what an enormous difference there may be in the receipts from towns of the same size, and one must understand the local conditions to appreciate even vaguely the enormous variations. For example, with towns of 12,000 or 15,000 the variation is from about 40 cents per capita to $8.40 per capita, the maximum receipts for towns of this size being twenty-one times the minimum receipts in some other town of same size. With larger cities the variations are less marked, but even here in cities of from 160,000 to 200,000, or say 180,000, the minimum receipts are about $4 per capita, the maximum about $11.60, and the average about $5. To some extent the great differences in receipts in cities of small size will depend on *character of service given*, including *frequency*, *speed*, *size and type of cars*, and *stopping places*. Riding will naturally be encouraged by frequent service of cars at high speeds, and also by convenient stopping places; but if there are too many of the latter, the average speed will be diminished, and this in turn will discourage riding, so that even in this matter of stopping places a study should be given to arrange for a happy medium, well adapted to local needs. Cars should be carefully selected as to size and type to meet the local climatic and other conditions after a study of the number and character of rain storms, the amount of hot and cold weather during each year, etc.

One of the most important of all elements determining possible gross earnings is what is here called the *riding factor* of the tributary population. This depends on (1) *Character of people*, (2) *Race*, (3) *Climate*, (4) *Average income*, (5) *Occupation*, (6) *Amusements available*. People in a hot climate will naturally ride much more than those in a temperate or cold climate, while in bitterly cold weather the riding in any city is greater than during moderately cool weather, the protection from the weather and the grateful warmth of heated cars being an attraction in such weather as is frequent during the middle winter season in the cities of the northern part of the United States and Canada.

People of an indolent and pleasure-loving race will ride to a much greater extent than those of an energetic and industrious race. In proportion to their incomes, the negroes in the United States and the mixed Latin and native races in South America will ride more frequently than the Anglo-Saxons in the same territory. When it comes, however, to Orientals, their habits differ so radically from what we are used to, that their riding is likely to be little in proportion to their incomes, which in turn are usually very small.

The *occupation* of the people in the neighbourhood of a tramway is of great

STREET RAILWAY STATISTICS.

	New York Surface.	Buffalo, N.Y.	Rochester, N.Y.	Washington, D.C.	Dublin.	Bristol.	Liverpool.	Perth, West Australia.	Paris.	Hamburg.	Brussels.	Buenos Ayres.	Tokio
Population	2,060,000	400,000	175,000	280,000	350,000	330,000	690,000	40,000	3,080,000	630,000	550,000	750,000	1,230,000
Miles of Track	389	184	103	168	87·2	37·25	64	12·5	230	145	...	94	25·4
,, ,, per 1,000	·19	·46	·59	·60	·25	·113	·093	·31	·0747	·23	...	·125	·0207
Weight of Rail	...	62–94	45–107	60–95	...	94							
	£	£	£	£	£	£	£	£	£	£	£	£	£
Bonded Debt	14,720,000*	1,940,000	970,000	2,003,000	479,900	100,000	175,100	97,563 †					
Floating Debt	5,490,000	313,000	70,000	...	5,092	46,522	119,679	5,944 †					
Stock	13,000,000	1,231,000	1,030,000	3,695,000	1,199,870	658,800	1,637,969	175,729 †					
Total Liabilities	33,210,000	3,484,000	2,070,000	5,698,000	1,684,862	805,322	1,932,748	278,336	4,770,000§	1,444,000‖	895,000‖	5,080,000‖	77,400
,, ,, per Mile	85,300	18,900	20,100	33,900	19,300	21,600	30,200	22,300	20,700	10,000	...	54,000	3,040
,, Bonds	37,800	10,500	9,420	11,900	5 500	2,680	2,730	7,800					
Gross Receipts	3,773,000	371,000	180,400	462,000	228,249	158,728	449,301	37,800‡	1,430,000	384,000	219,000	857,000	52,800
	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.	Shillings.
,, ,, per Capita	37·7	18·5	20·6	33	13	9·6	13	18·9	9·3	12·2	8	22·8	·86
									£	£	£	£	£
Operating Expenses	1,985,000	199,700	106,200	295,000	141,515	108,234	352,280	23,800	1,225,000	247,000	140,000	662,000	25,700
% Main Way	...	...	14 %	...	4 %	17 %	3 %						
% ,, Equipment	...	...	15 %	...	4 %		2 %						
Generation	...	...	...	...	15 %	68 %	86 %						
% Traffic Expenses	...	...	57 %	...	48 %								
% General Expenses	...	...	14 %	...	29 %	15 %	9 %						
Earnings from Operation	1,788,000	171,300	74,200	167,000	86,734	50,494	97,021	14,000	205,000	137,000	79,000	195,000	27,100
Fixed Charges	1,113,000	121,200	61,000	96,000	19,077	5,245	34,993	4,878					
Net Income	675,000	50,100	13,200	71,000	67,657	45,249	62,028	9,122					
% Operating Expenses of Gross Receipts	53 %	54 %	59 %	64 %	62 %	68 %	78 %	63 %	86 %	64 %	64 %	77 %	49 %
Car Miles Run	...	10,268,583	4,904,480	...	6,550,000	...	9,210,000	...	...	14,480,000	4,210,000	17,462,000	
,, ,, per Capita	...	25·7	28·0	...	18·7	...	13·3	...	...	22·9	7·7	23·3	
		Pence.	Pence.		Pence.		Pence.			Pence.	Pence.	Pence.	
Gross Receipts per Car Mile	...	8·67	8·83	...	8·36	...	11·74	...	...	6·37	12·5	11·78	
Operating Expenses ,, ,,	...	4·67	5·2	...	5·18	...	9·2	...	...	4·10	8	9·10	
Earnings per Car Mile	...	4·00	3·63	...	3·18	...	2·54	...	...	2·27	4·5	2·68	
				12 Companies.			Includes Elevated.		11 Companies represented.	1 Company represented.	1 Company represented.	5 Companies represented.	1 Company represented.

* Includes Guaranteed Rent Stock. † Balance Sheet, 30th June, 1900. ‡ Estimated from Earnings of 4½ months, ending February 15th, 1901. § Investment. ‖ Capitalization.

importance, it being found that those who have regular daily employment, such as work in factories or mills, will ride more frequently than any other class of population. This is due partly to the fact that the tramways are used by these people in going to and from their daily work, and partly to the fact that the tramway becomes their means of pleasure riding as well. In warm climates pleasure riding becomes one of the important sources of income to a tramway, and all reasonable means should be employed to encourage this riding.

OPERATING EXPENSES.

Operating expenses, while affected by other minor conditions, are determined largely by the following:—(1) *Wages of employees*, (2) *Size of tramway*, (3) *Permissible speed of cars*, (4) *Cost of fuel*, (5) *Cost of maintenance*.

The importance of being able to run cars at reasonably high speeds has already been dwelt upon under "Franchise conditions," and this is worthy of careful consideration. It is evident that the operating expenses will be affected directly by the cost of labour and fuel, and that the office and general expense of the company will be proportionately less with large than with small tramways. It is equally plain that the maintenance of a property will be less when the character of construction is of high grade, reasonably high first cost being further justified by the fact that a more regular and satisfactory service can be given with thoroughly first-class than with cheaper construction.

In studying the operating expenses of any tramway, one should know the local conditions, and then see that sufficient charges are made under operating expenses to fully meet the reasonable maintenance requirements.

This study can be assisted by comparison with results actually obtained on other properties, and it is well to compare the results reported by any tramway with those actually attained elsewhere. Such a comparison will never lead to infallible results, but is of use in helping to ascertain whether the operating expenditures are higher than would naturally be expected in any department, or whether the expenditures for repairs and maintenance are less than sufficient to maintain the property in thoroughly good condition.

NET EARNINGS.

The net earnings are usually understood to be the total earnings or gross takings less the total operating expenses after having deducted sufficient to fully cover the depreciation charges and amortization. As already pointed out, incorrectly reported net earnings are usually due, not to any falsification of accounts, but to insufficient provision for depreciation, and to charging against capital account items which, on a conservative basis, should be charged against operating expenses, usually under "Renewal Account."

The latitude permissible in varying these charges without bringing disaster to the company will depend to a considerable extent on duration of franchise and the growth of population tributary to the property.

With a perpetual or extremely long term franchise and a rapidly growing population, it might be possible that the increased earning capacity, owing to growth of tributary population, would alone fully offset any depreciation to property not covered by the daily charges to "Repair Account." With limited franchises, however, and with less rapidly growing populations, it is of the utmost importance that ample provision for depreciation should be made, and ordinarily investors will find

that this, more than any other single feature of the accounts of a tramway, needs careful investigation.

POSSIBLE FIELDS FOR PROFITABLE INVESTMENT.

In a general way there is no class of security which is really safer than that of a good tramway property. In nearly all cities there is a moderate growth in population, giving the tramway property a naturally increasing earning capacity and value.

The present tendency is universally toward the increasing concentration of population in large centres. This is naturally beneficial to tramways, and in an active progressive city under a reasonable franchise or concession a good tramway should be one of the best possible forms of safe and permanent investment. For the *permanent investor* there are opportunities in all parts of the world. In America there are many issues of first mortgage bonds which can be purchased on a basis netting the investor from $4\frac{1}{2}$ to $5\frac{1}{2}$ per cent. per annum, where the principal is amply secured by a property earning two or more times its total interest charges, and at the same time increasing from year to year in value. Bonds of this kind on a property in any prosperous and growing city can be confidently recommended.

Similar opportunities for investment may be found in the securities of established tramway companies which have several years' record of actual earnings in the better cities of other parts of the world. In these cases the same precautions as to depreciation and amortization will be required, and usually more careful study will have to be given to terms of concession and to other conditions which might affect the value of the securities.

For the investor who wishes to combine reasonable safety with a higher return there are occasional opportunities to be found in nearly all parts of the world. In America the building of new profitable lines must be confined largely to those projected to connect various towns and cities. The encouraging feature about these properties is that, if a wise selection is made, the investor may secure a property having a perpetual or long term franchise which will pay a high rate of interest on its first cost, and in addition to this will increase rapidly in earning capacity and value, due to the natural growth of its tributary population. Such properties are therefore quite worthy of consideration, but should be scrutinized most carefully, and proceeded with only after most conclusive evidence that they can earn a good rate of interest on their probable cost.

In England profitable investments in new roads are limited largely to this same class of inter-urban properties, due to the fact that in nearly all the cities of considerable size the municipalities themselves insist on owning and operating their tramways.

In certain portions of Great Britain the population is so concentrated that there should be numerous opportunities for profitable investment in lines of this character.

The discouraging features, however, are that the speed of cars must be slow, the first cost of construction due to the requirements of the Board of Trade and local authorities extremely high, the average income of the tributary population is comparatively low, and the natural desire to travel from one town to neighbouring towns is apparently less in Great Britain than in America. For the above and other reasons a much larger tributary population seems to be necessary to make a road profitable in Great Britain than in America. While in the latter a tributary population of 1,500 or 2,000 people per mile will

usually be sufficient to make a road profitable, statistics available to date seem to indicate that in Great Britain the tributary population should be fully 5,000 per mile of route, but this experience has been so limited that no general rules can as yet be fixed.

The high speeds necessary to encourage travel on inter-urban lines can best be obtained in America by having the railway own a private right of way. The tendency in this direction may perhaps be best illustrated by reference to a road of this character which is now being built by the New York firm with which the writer is connected. This road is to connect two cities of about 300,000 and 150,000 population respectively, distance between the centres of the two cities being about sixty miles. The population between the two cities is comparatively small, but in spite of this a high-grade railway is being built. The cars of this line will run from the centre of one city to the centre of the other, using the tracks of the local tramways within the city limits at each terminus, but the line will have its road bed largely over private right of way between the city limits, a distance of about fifty-five miles. The cars for this road are of the long bogie-truck type, and each will be equipped with four 75 h.-p. motors, so that it will be able to make a speed of about sixty miles per hour in the open country, and still be able to run at ordinary tramway speed within city limits. The entire fifty-four miles of route is to be operated from one generating station by means of high tension alternating distribution to substations, provided with rotary transformers, so that the cars are equipped with motors of the ordinary direct current type operating normally at 600 volts.

Some developments of a similar character will be justified in Great Britain, and to those who are fortunate enough to select the right locations very considerable profits will no doubt accrue. The first cost of right of way is, however, so great, that a considerably higher investment must be faced in undertaking such a road in England, and consequently materially higher gross takings must be looked for.

So far as the conversion of horse tramways to electric tramways by private companies is concerned, the field is at present limited largely to South America, Asia, and Australia. There are perhaps in all of Australasia a dozen places where horse tramways might profitably be converted to electric, or where new electric tramways might be built with profit. A table on page 354 gives some statistics as to tramways in various parts of the world, and an inspection of the returns from the tramways at Perth, West Australia, will show that the receipts per capita are high in proportion to the population. Similar results are shown in other Australian cities, it being evident that the climatic conditions are favourable to induce riding, and this, combined with the active character of the population and the fact that the incomes of the working classes are on the average rather high, all contribute to large tramway receipts. Similar large receipts are shown by other Australian tramways, and also by the remarkably satisfactory record of the Cape Electric Tramways at Cape Town, South Africa. Here the character of population and climate is generally similar, and the tramway returns have been most satisfactory.

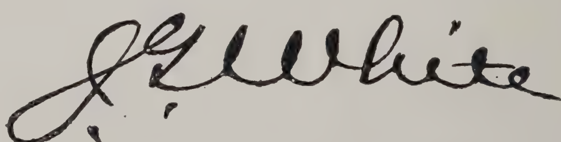
From statistics available it seems probable that the average receipts per capita will be quite as high in Australia as in America for cities of the same general size and type. While, therefore, there are a few good opportunities for investment in Australia, and while there will undoubtedly be a few similar opportunities in South Africa, the tendency to be avoided seems to be against

accepting from the local authorities franchises or concessions with such onerous conditions as to low fares and other terms, that comparatively little profit is likely to be realised by those finding the capital for building or reconstructing the tramways.

In Asia there are a number of cities with large population in which it would naturally be expected that tramways could profitably be developed. Difficulties arise, however, partly from the narrow streets, and partly from the fact that the Oriental population of these cities is usually very poor and unable to spend much for tramways or any other method of travel, and that the habits of this Oriental population are such as to lead to comparatively little travel. An inspection of the column showing the receipts of the tramway of Tokio, Japan, will show such very low returns as to indicate that one should undertake the construction of a tramway in any Oriental city only after most careful study and consideration.

In South America, on the other hand, the returns of the tramways at Buenos Ayres (the majority of these being still operated by horses) show exceptionally large takings in proportion to the population. Similar large returns are shown by horse tramways in other South American cities, and by the few electric tramways in operation. Here we have climatic and race conditions contributing to large tramway receipts, the discouraging conditions being the unstable governments prevailing in many of the South American countries, and the further fact that in a number of South American cities the sanitary conditions are unfavourable and mortality high. This, of course, applies only to a portion of these cities. Even with a change in government the tramways are usually not affected, and the majority of South American cities are growing and are likely to develop largely in size and wealth. Concessions can be had which are satisfactory as to period and general conditions, including rates of fare. With careful study of local conditions, there seems no reason why the purchase of some of the horse tramways of South American cities, and their conversion to electric traction, should not prove to be an exceptionally profitable investment.

In general, we may conclude that while there are occasional opportunities for profitable tramway investment in almost any part of the world, nevertheless only a few of the projected enterprises are worthy of support, and a most careful study should be made to insure the selection of only the worthy projects, and the expenditure of capital invested in such a way as to bring permanently the best returns possible under the existing circumstances.



LIGHT RAILWAYS.

By J. WALWYN WHITE.

IT is a melancholy fact that light railways have not, by any means, proved the boon and blessing to the struggling farmer and others in our country districts that was fondly anticipated when the Light Railways Act was passed in 1896. I have often been asked recently, "How is it that light railways have not progressed in this country? How is it that we hear so little of them?" The reason, I think, is not far to seek.

Let us examine the list of Light Railway Orders that have been confirmed by the Board of Trade from December, 1897, to the present time. There we find a total number of ninety-six proposed "light railways" authorized to be built.

But are they *light railways* as generally understood by the average "man in the street"? In analysing this list we find that no fewer than sixty-three of these so-called "light railways" are of the standard main-line gauge of 4 ft. 8½ in., with an average estimated cost per mile of £7,000 to £8,000, exclusive of rolling stock; whilst only six of these lines are of 3 ft. or less gauge—and such as most reasonably might be properly termed *light railways*. Of the remainder, amounting to about twenty-three per cent. of the total, the bulk appear to be merely ordinary street tramways with electric traction, and which, in the usual way, would have probably been built under the old Tramways Act of 1870, but for the greater facilities offered by the Light Railways Act. At all events, they appear to be almost entirely intended for passenger traffic only, and not for goods traffic, such as farm produce and manufactured or raw materials, for which the Light Railways Act was originally intended.

Now this is not as it should be. This country imports annually about £30,000,000 worth of farm produce, apart from corn and flour, consisting mainly of butter, cheese, eggs, and other items of food that could be readily produced in the agricultural districts of our own land if the farms of the outlying districts, in the sparsely populated portions of the United Kingdom, could only get their produce quickly and cheaply to the large towns and industrial centres. And yet, in spite of the facilities offered for building light railways by the legislature, this cannot be done, and the hard-earned money of the teeming workers of England must needs go to fill the pockets of foreigners, whilst our farmers and landowners, who work the land at any distance from a large town, find it difficult to exist. Why is this so?

It seems that a large proportion of the blame must rest with the promoters and engineers of these so-called light railways to which I have drawn attention. The thinly-populated districts, where agriculture is the principal business, cannot provide sufficient traffic for an expensive standard gauge railway, and yet the engineers whom the promoters call in, will keep on specifying for heavy standard lines, with heavy rails, expensive bridges, and costly appointments

generally, with the result that the cost comes up to such a large figure that the promoters are frightened, and find themselves unable to secure the necessary capital; or, if they do succeed in getting the money, the returns are so much out of proportion to the capital expenditure, that the railway which was to work such wonders, languishes along for a year or two, and is finally absorbed by one of the large railway companies.

This is no fancy picture—it has happened over and over again, and will continue doing so, until the engineers can make up their minds to content themselves with real "light railways," built with light rails on a narrow gauge, and with a real light railway equipment, instead of standard work. It is true that probably such a light railway would not enhance their reputation so much as a standard line, but there is no question as to the feelings of the shareholders at the end of each year's working.

A light railway, in the true sense of the term, can be built and equipped complete, including cost of the land at agricultural value, and rolling stock, for about £2,500 per mile, and such a railway would yield a handsome dividend with traffic returns of only £7 or £8 per mile per week, whilst at the average cost of the so-called "light railways" to which I have referred, such a revenue would only mean starvation.

For agricultural countries a much larger traffic than this £8 per mile per week could not possibly be looked for, and an ordinary light railway of 2 ft. 6 in. gauge, costing the amount I have indicated, would be capable of accommodating all the traffic that could possibly come over it, both goods, merchandize, farm produce, and passengers. Yet, in spite of all this, our engineers still continue prescribing costly standard lines that could take more than fifty times the amount of traffic that could ever possibly offer itself.

I have already intimated that (in my opinion, at all events) a light railway should have a gauge of not more than 3 ft.—indeed, I consider a gauge of 2 ft. 6 in. ample for any ordinary traffic in agricultural districts—and the reasons for fixing this gauge are many and important.

In the first place, it must be borne in mind that the largest factor of cost in a standard gauge railway is not in its steel rails, or permanent-way, but in the preparation of its "formation," usually styled "earthworks," including excavating the "cuttings," and filling up hollows in the contour of the ground by "embankments," in order to ease the gradients of the line as much as possible.

It will be readily seen that the narrower the gauge the less the amount of "earthworks" will be involved, but this is not all—a narrow gauge line will permit of sharp curves being used, which would not be possible on a standard gauge road. A $2\frac{1}{2}$ ft. gauge road would work efficiently with curves of 200 ft. radius, whilst a 200 *yards* curve would be too sharp for economical working on a standard gauge line; consequently our narrow gauge line would be able to readily run *around* hills, or other obstacles, that would require to be taken direct by the broader gauge line, either by tunnelling, or by "cuttings."

Then, again, the matter of "severance," or dividing up of land, is not so serious a matter with the narrow gauge, as bridges or tunnels, if used, would be much smaller and cheaper in every way; and the gradients employed on the highway leading to these would be much less severe, an important consideration where heavily loaded farmers' carts are concerned. (See Fig. 1 for cheap Narrow-gauge Railway Bridge.)

And this brings me to another point. The average engineer is generally proud (and rightly so) of the beautiful bridges he designs for highways crossing our

railways. But I venture to think that these elaborate bridges, with their costly approaches and embankments, which swallow up so much money, are not always necessary, and their place could readily be taken by a level crossing, especially in country districts where only a few trains are run per diem.

"But," says the engineer, "these crossings will need caretakers, to open the crossing gates on the approach of the train, and close them again after the train has passed by."

This objection is readily overcome by the use of one of the several types of automatic level crossing gates now on the market.

The principle on which the best of these gates work, is that the passing train, by engaging a lever fixed some few hundred yards away from the gates, winds up a weight, instead of moving the gates direct; and this weight in turn moves the gates over to the required position, without shock, and independently of the speed at which the train is going. In addition to this, if any obstruction got in the way of the gates opening for the train, say a child, or an animal, there is only the pressure due to the falling weight exerted against this obstruction (see Fig. 7), so that the gates come to a stop, the signals at the gate remaining at "danger," and so bringing the train to a stand. As soon as the obstacle moves out of the way, the weight completes its downward travel, and opens the gates, which pull the signal "off" in so doing, thus permitting the train to pass. The reverse operation takes place after the train has gone by.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

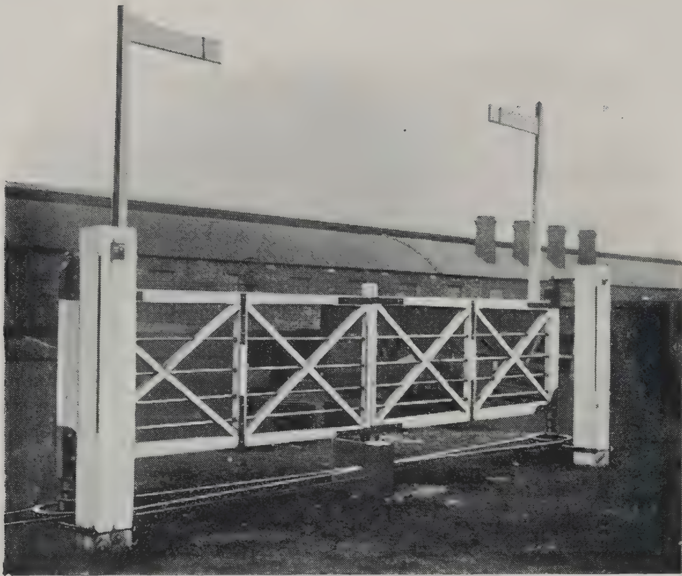


FIG. 5.—WHITE'S AUTOMATIC LEVEL-CROSSING GATES.

In this way the gates are opened and closed by the passing train, in any weather, without danger to the public on the highway.

A light railway of 2 ft. 6 in. gauge, with steel rails weighing only 30 lbs. per yard, will safely carry loads of eight tons on two axles, whilst heavier loads could be carried by increasing the number of axles. And such a line, whilst it would return a good dividend with traffic receipts of only £7 per mile per week, is really capable of accommodating traffic up to £50 per mile per week, should this amount offer itself.

Then, too, the working expenses on such a narrow gauge line are much less in proportion to those on the standard gauge railway, owing to the lighter build of rolling stock, and the lesser speed usual on the former. It is a well-known axiom amongst railway men that the greater the speed, the greater the expense in every direction.

It is quite an easy matter to work a train service of 25 miles per hour over a light railway with 30 lbs. rails, and 2 ft. 6 in. gauge, with curves of a minimum radius of 50 yards, and ruling gradients of 1 in 40 or 50, which could scarcely be done on the normal gauge with ordinary rolling stock.

I would, however, prefer average gradients of, say, 1 in 80, with curves not less than 250 ft. radius, as much as possible, thereby saving engine power, and only using the steeper inclines and sharper curves where absolutely necessary, to save the cost of expensive cuttings, bridges, or embankments, etc.

To show the advantage of having the gradients as easy as possible, I give the average tractive force of steam locomotives on different gradients in annexed Table.

It will thus be seen how much the very steep gradients minimise the hauling power of the locomotive, though if the inclines are but short, and the engine gets a good start, it will take up much heavier loads than those I have stated, owing to its momentum.

The eight items essential for the satisfactory progress of light railways in this country are, in my opinion :—

1. The permanent work should be simple and cheap.

2. Level crossings should be employed instead of bridges, the gates, of course, being kept shut against the train, leaving the road open, and the gates to be automatically opened and closed by the passing train.

3. Cheap but effective fencing to be permissible.

2 FT. 6 IN. GAUGE. AVERAGE SPEED, 15 TO 25 MILES PER HOUR.

	Will Haul on the Level	On Gradients of		
		1 in 100	1 in 50	1 in 25
Locomotive with 8 in. diameter cylinders ...	200 tons	70 tons	39 tons	20 tons.
,, 10 ,, ,, ,, ...	340 ,,	110 ,,	65 ,,	35 ,,
,, 12 ,, ,, ,, ...	450 ,,	150 ,,	90 ,,	50 ,,

These figures, of course, will vary with the condition of the line and the rolling stock, and the state of the weather.

4. All unnecessary paraphernalia, such as stations, station-masters, gate-keepers, elaborate signals, interlocking gear, continuous brakes, etc., should be dispensed with.

5. The compensation for land or way-leaves should be optional for payment by annual instalments, instead of a large sum of money down, which might seriously cripple a small company.

6. The permanent way, though of a cheap character, should still be good and substantial, in order to reduce the yearly maintenance expenses, both of way and of rolling stock; for this purpose I consider steel or metal sleepers of some sort to be essentially requisite, and all laid on a good, ballasted formation.

7. The land should be sold or rented at its agricultural value in the country, nothing being charged for compulsory sale or severance on rural properties deriving any benefit from the railway.

8. And lastly and most important, the gauge should be narrow, and not exceeding 3 ft.

Mr. R. C. Rapier, chairman of the Southwold Narrow-gauge Railway, gives five advantages in using narrow-gauge feeding lines instead of standard gauge, even when including break of gauge:—

(*a.*) The Railway Clearing House, in the division of traffic earnings, allows more than the cost of transhipment, viz., 9*d*. per ton, to the Narrow-gauge Company, and that makes a profit in itself.

(*b.*) The working expenses are certainly less.

(*c.*) The rolling stock of the small company does not get scattered all over the kingdom.

(*d.*) The heavy engines of the main line cannot trespass on the light railway, and so damage it.

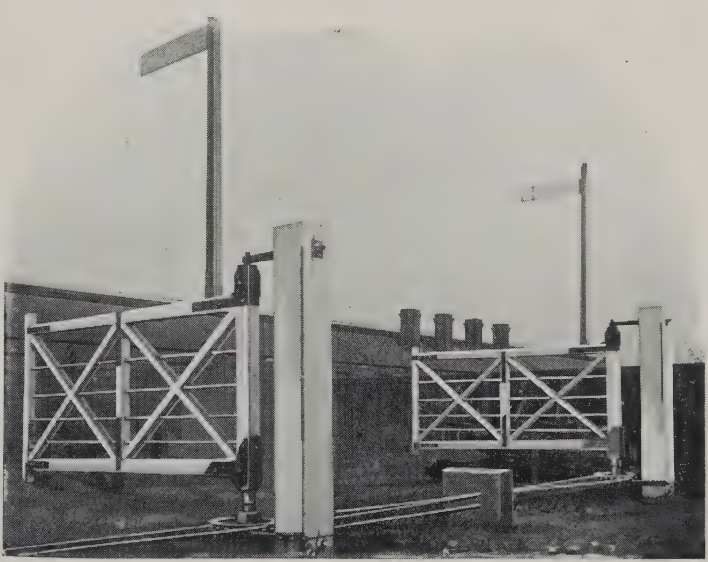


FIG. 6.—VIEW SHOWING AUTOMATIC LEVEL-CROSSING GATES OPEN, WITH SIGNALS AT "DANGER."

(*e*.) The rolling stock can be built much lighter than standard-gauge stock.

The working expenses of the Southwold Railway, of only 9 miles length, are about £4 5*s*. per mile per week. The gauge is 3 ft.

Traffic amounting to only £5 per week per mile should justify an expenditure of £3,000 per mile. As a general rule, the interest on capital and the working expenses should be about equal, and the nearer the two coincide the better.

Narrow-gauge lines will carry 5 to 6 tons of paying load to 2½ tons of dead weight, against 6 to 4½ on standard gauge. The carriages are preferably constructed on the bogie system, to carry an average of forty passengers each. The accommodation is found sufficient, and the motion is at least as smooth as on first-class constructed railways.

Narrow - gauge railways constructed through rough countries contrast most favourably with wide lines in point of cost. But even through level countries, apart from the saving in land, permanent way, rolling stock, etc., the advantages are very great, in avoidance of heavy bridges, road approaches, and expensive lands and buildings, by the introduction of curves and gradients not possible or applicable on a wide-gauge line.

On a 2 ft. 6 in. gauge railway, having 2 ft. diameter wheels, and waggons 5 ft. wide, the cross-section of the load (which may be 3 ft. 6 in. high) is 17½ sq. ft., having an angle of stability of 36 degrees, which is ample for all practicable purposes.

Such a railway enables waggons of a size convenient for the general requirements of the traffic to be met with, in thinly populated districts, to be constructed with economical proportions, instead of running big, heavy waggons capable of carrying 8 tons or so, with only one or two tons of paying load in them, as is frequently the case on standard-gauge lines.

A great deal has been said on the subject of break of gauge, involving the change of material and goods from the narrow to the standard gauge, and *vice versâ*, at the junction station; but far too much has been made of the apparent difficulty. As a matter of fact, the cost of transferring goods from narrow to broad gauge on the Festiniog Railway is ¾*d*. per ton for minerals, 1½*d*. per ton for general goods, and 6*d*. per ton for fragile material, like slates, *by hand*.

With regard to fish, farm produce, and other goods, which would not stand rough treatment, I have adopted the following plan on a narrow-gauge line my firm equipped some time ago :—

The line is 2 ft. 6 in. gauge, and is principally used for carrying coal to a gasworks, a distance of about two miles. The waggons used on the tramway have steel frames, carrying the wheels and axles, etc.; at each end of the frame or bogie is a standard, high enough to carry the tipping trunnions, which are mounted on the wooden boxes which carry the coal. These wooden boxes are about 4 ft. 10 in. long, 3 ft. 8 in. wide, and 3 ft. deep, carrying about 2 cubic yards each of coal (say 1½ tons), and are so made that six boxes exactly fit into an ordinary standard-gauge waggon. This main-line waggon, with its six tipping boxes, travels to the colliery, where the boxes are all filled with coal in the ordinary way, then conveyed to the terminus of our narrow-gauge railway, where there is a light portable crane. Each box is then lifted out of the main-line waggon and deposited on to the bogie frame, standing in readiness on the narrow-gauge line, while the six empty boxes off the bogies are put into the main-line waggon, and sent to the colliery for a fresh load of coal, the cost of this transfer being about one halfpenny per ton.

The full boxes are conveyed along the

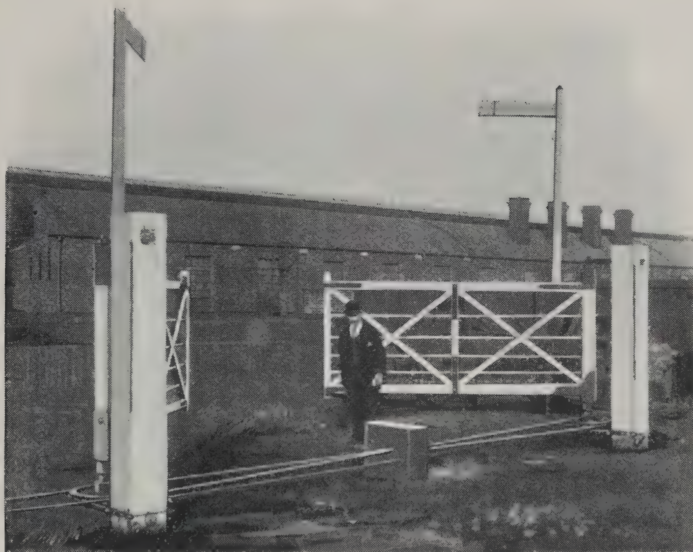


FIG. 7.—SHOWING OBSTRUCTION PREVENTING THE GATES CLOSING.

narrow-gauge line to the gasworks, and tipped by means of the before-mentioned trunnions (by which they are suspended in the bogie frames) direct into the gasworks bunkers, or alongside the retorts. There is thus no break of bulk whatever from the colliery right to the mouth of the retorts.

A similar plan could be adopted on an agricultural railway by using boxes of such a size that four would sit in an ordinary main-line waggon, say 7 ft. long by 4 ft. 10 in. wide by 3 ft. deep, with about $3\frac{3}{4}$ cubic yards capacity.

Each farmer, through or near whose land the light railway passes, would preferably have his own siding or branch line, where full or empty trucks could stand. He fills his produce, be it hay, straw, potatoes, or other vegetables, dead meat, etc., into these loose boxes in his own farmyard; then he carts these boxes to his siding (if the siding does not run directly into his farmyard), and with a light portable crane loads the full boxes on to the bogie trucks waiting on the railway. The next train going along picks up these loaded trucks and takes them to the terminus, where the light railway runs alongside the main-line waggons. A similar crane loads these boxes into the main-line waggons as before, which run them off to the great market town, where again the same boxes can be loaded on to consumers' carts, and thus carted directly to their destination, without any break of bulk or handling of any kind, from the farmyard. The boxes, when empty, could be returned in a similar manner, loaded with manure or other goods, or, the sides being made collapsible, may be packed up and returned to the light railway as returned empties, taking up very little room.

Of course, if the light railway itself runs direct to the market town, without the intervention of the main line, there would be so much less transferring necessary, but I have assumed an extreme case for the purpose of my argument.

Where the light railway goes through ordinary well-drained meadow land, a ready way of preparing the formation *for a commencement*, is simply to plough the land along the route to the required width of formation (say 7 ft. 6 in. for a 2 ft. 6 in. gauge line), turning the ground

inwards from each side, which thus makes the track slightly raised above the general level, with a drain on either side.

A few inches of stone or gravel ballast over this completes the formation, for a surface line, ready for the sleepers and rails; the thickness and quality of this bottom ballast or "pitching," of course, depending on the general nature of the ground and amount of traffic over the line.

If good coarse ballast is scarce, and the ground is of a clayey nature, a cheap way of preparing good ballast is to burn the clay got from the "cuttings" with coal or slack, putting a layer of fuel between each layer of clay, and forming the whole into a large heap of burning material, something like a brick-kiln. The clay is thus burnt into a kind of "brick-bat," and makes excellent bottom ballast, if burnt sufficiently hard.

The rails being laid, the material for the top ballasting is run along the line, in tipping waggons as required, then tipped on either side, and spread around the track and under the sleepers, the sleepers being lifted with levers or "jacks" to the required heights, as indicated by the "sighting-boards," and packed to that level with the ballast.

I will now give a fairly approximate estimate of the cost of building a good, substantial, narrow-gauge light railway, with working expenses and receipts.

I will take as my basis a single line ten miles long, equipped with sidings, and running through mainly agricultural country, with a small manufacturing village on the line of route, or at the terminus.

I will assume that we lay our line in first-class condition on a properly ballasted formation, but mainly following the ordinary contour of the ground, with minimum curves of 250 ft. radii, and maximum gradients of 1 in 30, the ruling gradients being 1 in 60.

The rails would be of steel, weighing 30 lbs. to yard, with fish-plated joints, and with steel sleepers 4 ft. 6 in. long, as shown in Fig. 10 herewith.

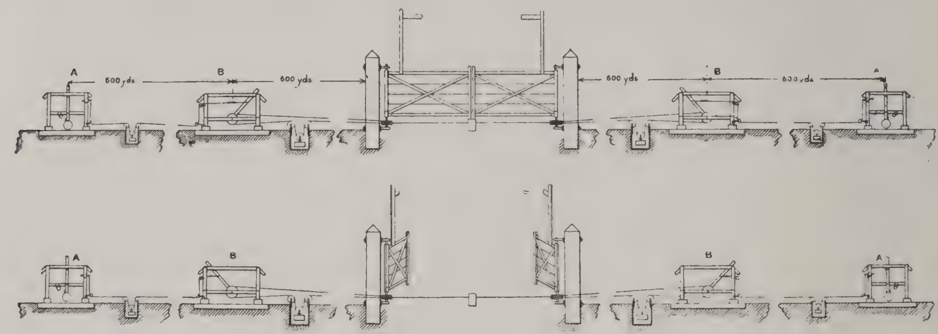


FIG. 8.—DIAGRAMMATIC VIEW SHOWING CONNECTIONS OF AUTOMATIC GATES.

Such a line would stand a lot of wear and tear, and require very little attention or maintenance, and would certainly last, with ordinary care, for more than the thirteen years on which I base my estimate.

The cost of laying such a railway with complete equipment would be about as follows:—

	Per mile. £	s.	d.
Steel rails, 47 tons, with steel sleepers, fish-plates, bolts, and all fastenings	450	0	0
Two sets of switches and crossings per mile, for sidings	20	0	0
Laying, ballasting, and ordinary earthworks for 7 ft. 6 in. formation	470	0	0
Fencing and occupation gates	220	0	0
Rolling stock, proportion per mile	250	0	0
Land, 2 acres at £150 per acre, average	300	0	0
1 set of automatic level crossing gates	150	0	0
Telephone and signals, etc.	100	0	0
Carried forward	£1,960	0	0

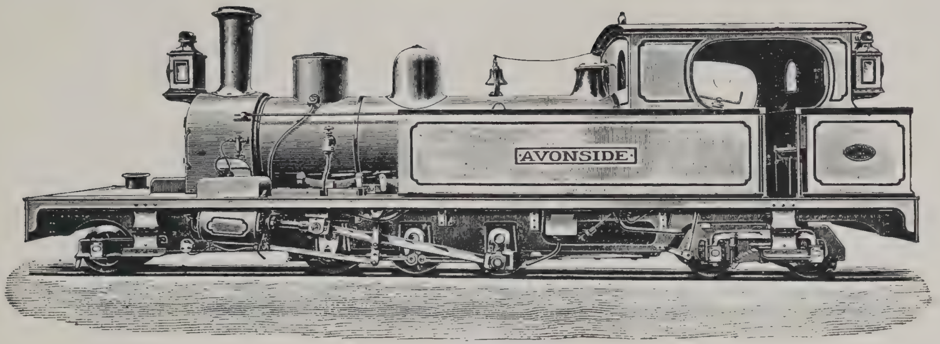


FIG. 9.—COMPOUND NARROW-GAUGE LOCOMOTIVE BUILT BY THE AVONSIDE ENGINE COMPANY.

	Per mile. £	s.	d.
Brought forward	£1,960	0	0
Proportion of station buildings, engine shed, water tanks, etc. ...	200	0	0
	2,100	0	0
Engineering, Parliamentary, and law costs and contingencies	240	0	0
Total cost per mile.........	£2,400	0	0

The total cost for the ten miles, equipped complete, being thus £24,000, of which one-third might be raised by debenture bonds, and say one-third by preference shares, and the balance by ordinary shares, if no municipal or Parliamentary financial aid were available.

We assume that our trains make six trips per day, three out and three home, as per annexed time-table.

Each train should carry on each journey approximately :—

	£	s.	d.
10 first-class passengers, average 1s. each	0	10	0
20 second-class passengers, average 6*d*. each..................................	0	10	0
Light goods, parcels, milk, and terminal charges	0	5	0
8 goods waggons, averaging 3 tons of load each—24 tons, at an average charge of 2*d*. per ton per mile, and averaging 6 miles each journey ...	1	4	0
Total receipts per train......	£2	9	0

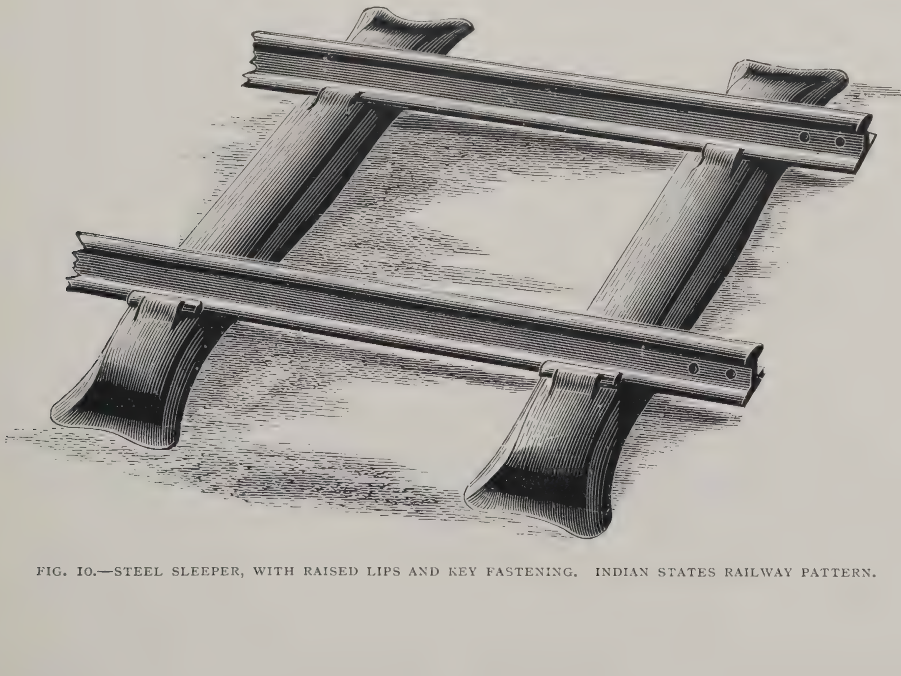


FIG. 10.—STEEL SLEEPER, WITH RAISED LIPS AND KEY FASTENING. INDIAN STATES RAILWAY PATTERN.

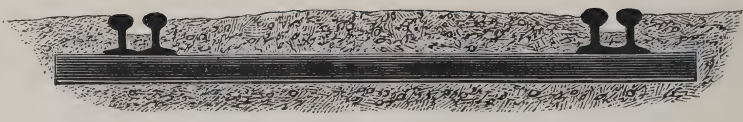


FIG. 11.—LEVEL CROSSING, FORMED WITH ORDINARY BALLAST AND GUARD RAILS.

Or £88 4*s*. per week, or £4,586 per annum, equal to £8 16*s*. per mile per week, or at the rate of 4*s*. 10*d*. per train mile. This is not reckoning on any revenue there might be from advertising, book-stalls, etc.

The estimated weekly expenditure would be :—

	£	*s*.	*d*.
1 secretary and manager	4	0	0
1 engine-driver	2	0	0
1 conductor	1	10	0
1 fitter and repairer and assistant engine-driver	1	7	6
1 shunter and porter	1	5	0
1 platelayer	1	10	0
1 labourer and boy........................	1	7	6
Weekly wages	13	0	0
Coal, 5 tons at 14*s*. per ton	3	10	0
Oil and engine stores.....................	0	15	0
Sundries, postages, etc.	0	15	0
Weekly expenses	£18	0	0

Our annual expenses should be about :—

	£	*s*.	*d*.
Wages, fuel, etc., as per list above, at £18 per week	936	0	0
Depreciation and maintenance on rolling stock at 10 per cent. per annum	250	0	0
Depreciation on permanent-way on £4,750 at 7½ per cent. per annum	356	0	0
Depreciation on fencing, gates, buildings, etc., on £6,500 at 10 per cent. per annum..................	650	0	0
Rates and taxes, etc.	200	0	0
	£2,392	0	0

Or £46 per week, equal to 2*s*. 6½*d*. per train mile, or at the rate of about 50 per cent. of the gross receipts.

Thus our installation at £2,400 per mile, say £24,000 in all, should yield us a clear profit of £2,194 per annum, or at the rate of about 9 per cent. per annum on the total cost.

TIME-TABLE FOR LIGHT RAILWAY.
(10 Miles long)

HOME AT TOWN TERMINUS.

Journey.	Dep.	Arr.	
	a.m.	a.m.	
1—Out.	8.0	8.50	Passengers and goods through.
From	8.50 to 9.30		Shunting and transhipping from light to standard gauge and *vice versâ* at the terminus.
2—Home.	9.30	10.20	Passengers and goods through.
From	10.20 to 11.0		Shunting, etc., at home terminus
		p.m	
3—Out	11.0	12.30	Passengers and goods, shunting and taking up loads, etc., from farm sidings on the way
	p.m.	p.m.	
From	12.30 to 1.30		Dinner.
From	1.30 to 2.0		Shunting and transhipping, etc , at main-line end.
4—Home.	2.0	3.30	Passengers and goods, shunting and setting down loads, etc., at farm sidings on the way.
From	3.30 to 4.0		Shunting, etc., at home terminus
5—Out.	4.0	4.50	Passengers and goods through.
From	4.50 to 6.0		Shunting and transhipping.
6—Home.	6 0	6.50	Passengers and goods through.

It has frequently been urged against narrow-gauge and light railways that they are but toys, capable of accommodating only small engines with low tractive force. The illustration in Fig. 9

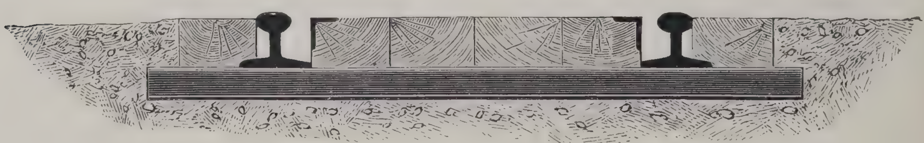


FIG. 12.—LEVEL CROSSING, FORMED WITH WOOD PLANKING, BOLTED TO THE SLEEPERS, AND PROTECTED WITH ANGLE IRON

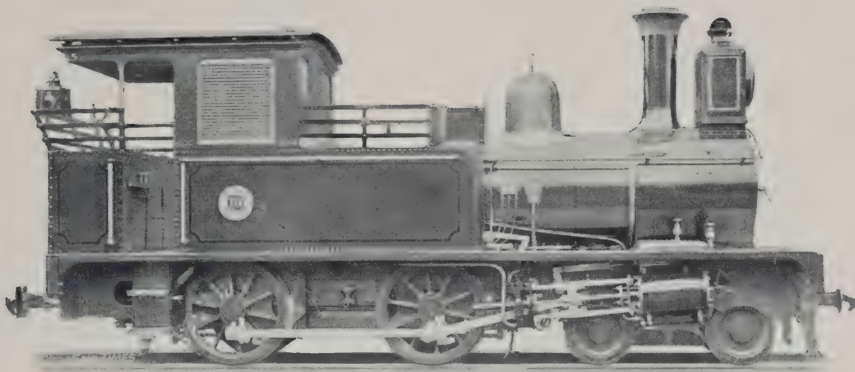


FIG. 13.—VIEW OF ENGINE BUILT BY THE HUNSLET ENGINE CO., LEEDS.

Gauge of Railway, 3 *ft.* $3\frac{3}{8}$ *in.* *Diameter of Cylinders*, 10 *in.* *Length of Stroke*, 1 *ft.* 4 *in.*
Diameter of Coupled Wheels, 3 *ft.* 3 *in.* *Diameter of Bogie Wheels*, 1 *ft.* 11 *in.* *Length of Coupled Wheel base*, 6 *ft.*
Length of Total Wheel base, 15 *ft.* 2 *in.* *Weight in Working Order*, 20 *tons.*

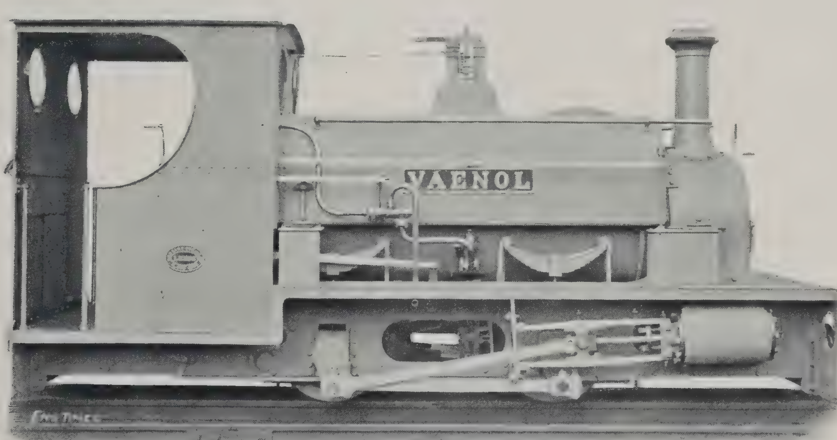


FIG. 14.—ILLUSTRATION SHOWING ANOTHER TYPE OF ENGINE FOR LIGHT RAILWAY WORK, BUILT BY THE HUNSLET ENGINE CO., LEEDS.

Gauge of Railway, 1 *ft.* $10\frac{3}{4}$ *in.* *Diameter of Cylinders*, $8\frac{1}{2}$ *in.* *Length of Stroke*, 1 *ft* 2 *in.*
Diameter of Coupled Wheels, 4 *ft.* 6 *in.* *Weight in Working Order*, $11\frac{3}{4}$ *tons.*

shows a type of compound locomotive which is somewhat novel—there being one high-pressure cylinder exhausting into a re-heating receiver in the hot smoke-box, and thence into the two low-pressure cylinders outside. This gives the same number of exhausts as an ordinary locomotive, and is effective in making a steady blast.

The engine (one of several built by the Avonside Engine Company for a 2 ft. 6 in. gauge railway in South America) is of the following dimensions, viz.:—

1 high pressure cylinder	15 in. diam. by 16 in. stroke.
2 low-pressure cylinders	15 in. diam. by 20 in. stroke.
Fixed wheel base	7 ft.
6 coupled wheels	3 ft. in diam., centre wheels having no flanges.
Trailing bogies (4 wheels) ...	2 ft. in diam.
Leading pony truck (2 wheels)	Do.
Heating surface, tubes.........	676 square feet.
Do. fire-box	70 do.
Tank capacity	860 gallons.
Bunker capacity	90 cubic feet.
Working pressure	180 lbs. per square inch.

Weight on any wheel not exceeding $3\frac{1}{2}$ tons.
(Sleepers are spaced about 2 ft. 5 in. centres.)

FIG 15.—CALTHROP'S NARROW GAUGE TRUCK FOR CARRYING STANDARD GAUGE ROLLING STOCK OR ORDINARY HORSE WAGGONS.

The rails used are of Vignolles section, weighing 36 lbs. per yard. In order to make an engine with a long total wheel-base accommodate itself to the road, all the coupled wheels and the pony truck are compensated together; and to give great lateral flexibility when on sharp curves, the rear bogie and front pony truck are free to move 9 in., subject to controlling springs. The draw-gear also,—which pulls from a point near the centre coupled wheels—can move laterally 10 in. at the buffer beam.

The adoption of compound engines was determined by the great cost of fuel and water they were to use, and it has been found in actual working that they save about 25 per cent. on these items over plain engines doing the same work. The engines are reported to run very steadily, and are probably the largest engines made for the 2 ft. 6 in. gauge.

The reversing handles are arranged so that both high and low pressure cylinders may be worked in various grades of expansion. The sanding is done by Gresham's steam sanding

apparatus. The starting apparatus is by a simple valve, which admits a small amount of high-pressure steam into the low-pressure cylinders; and it has been found in practice to be very effective. There is a safety-valve on the receiver to blow off at 125 lbs. per square inch. The engines have cabs of commodious pattern, having a clear working space for driver and stoker of 6 ft. by 4 ft. 6 in.

The tractive force of these engines is:—

High-pressure cut-off, $\frac{4}{10}$; low-pressure cut-off, $\frac{4}{10}$; 8·044 lbs.

High-pressure cut-off, $\frac{6}{10}$; low-pressure cut-off, $\frac{4}{10}$; 10·870 lbs.

I think it will be granted that a case has been fairly made out for the narrow gauge light railway, even where break of bulk is necessary at the interchanging station; but Mr. Everard R. Calthrop, some little time ago, brought out a most ingenious method of bodily conveying loaded standard gauge waggons along the narrow line, which seems to promise good results (see Fig. 15).

Where there is a fairly large amount of traffic to be anticipated for a proposed light railway, and yet not sufficient to necessitate a double line all the way, a good plan is to build the railway with three lines of rails, forming two roads, one up and one down, as shown in Fig. 4. Such an arrangement costs very little more than an ordinary single line, whilst requiring no switches at the passing places. The widening into two separate roads is effected merely by a simple vee crossing, without any switches or moving parts, as shown in Figs. 3 and 4, thus saving the cost of signalmen for operating the switches.

The great question, of course, is the means to be adopted for raising the necessary capital for these light railways.

In Belgium it is subscribed in the following proportions:—

The State	27	per cent.
The Provinces	28	,,
The Communes......	40·9	,,
Private individuals .	4·1	,,
	100·0	,,

I would recommend:—

One-fourth by the local standard main line, to which the light railway acted as feeder.

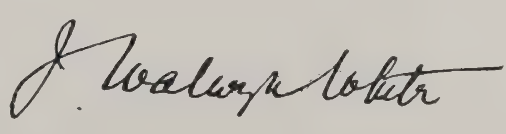
One-fourth by the local landowners through whose property the railway passed, and the value of which would be largely increased in consequence.

One-fourth by the county council.

One-fourth by the general public.

Whichever way the money is raised, the management should be retained by the Light Railway Company, and not allowed to revert, as is too often the case, into the hands of the neighbouring great railway.

With a proper system of such *cheap* light railways to act as feeders to the great lines, an impetus would be given to the great farming industries of this country, and a ready and cheap means would be provided for the working artisans in our crowded cities to get to healthy country homes, thus providing one means of overcoming the evil resulting from the existing overcrowding in our towns.



SOME NOTES ON RAILWAYS.

By W. G. BAGNALL.

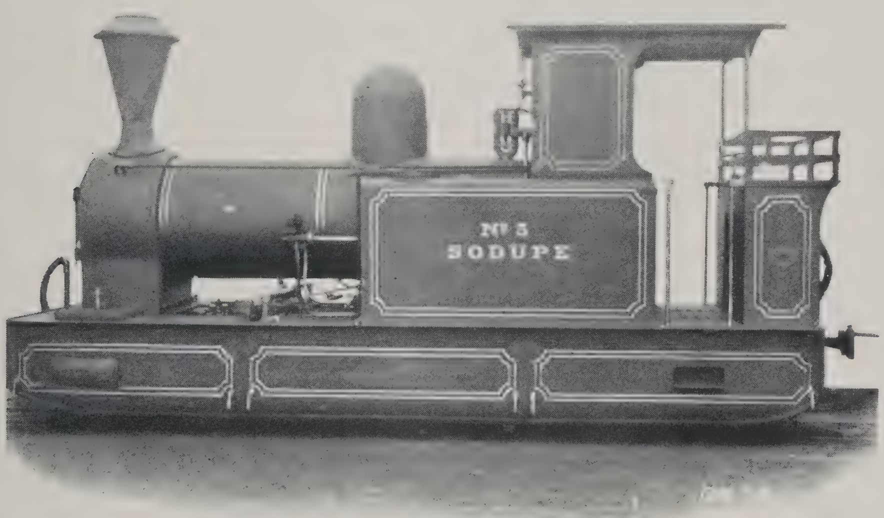
SO much has been written and said of late years on light railways that I doubt if more can be added to interest those readers who have not the wish to take up the subject as a special study.

One of the original and best known narrow gauge railways is the Festiniog. It requires no description, as so many have seen it. The gauge is 1 ft. 11⅝ in. That this has been a successful venture no one can for a moment doubt, but it has possibly led many astray. It was originally built to bring the slates down from the quarries only. The traffic has increased to such an extent that it is now doing work equal to many main lines abroad. The difficulties of working so narrow a gauge with increasing traffic have been overcome, but it is safe to say that such a gauge would not have been adopted in the first instance had the present existing bulk of traffic been foreseen. The necessary delay and engineering and physical complications in that particular instance made the change no doubt difficult, if not impossible, so notwithstanding the enormous development the original gauge was retained. Some twenty-five years ago, when there were not so many light railways on the continent, foreign engineers would ask for a "Festiniog," which really meant nothing more than a light railway of 60 centimetres, or practically similar gauge. Many, however, have made the mistake of adopting it where the traffic would have warranted a wider one. We know now that some countries—France, for instance—are practically intersected with narrow gauge railways, and it was thought by some who brought the question forward a few years back that the same thing would happen here for the relief of agriculture. Others who knew the agriculturists well thought differently, for, in the first place, the ordinary farmer requires no railway at all, for his grandfather had none; and, in the second place, he must have a full gauge, because he could not be "bothered with the light ones." Yet he is the first to complain when charged high rates on his goods, little realizing the enormous initial and working expenses on our main lines, and yet again he is the last to seek economy when expenditure is to be made to afford him help.

Thus, although an Act has been passed which greatly facilitates the making of railways and reduces the initial expenses and provides subsidies from both the Imperial Exchequer and County Councils, comparatively speaking but little progress has been made. A short time before the Act received the consideration of Parliament, I was asked if it was feasible to construct a light railway from a main line to a town of considerable size three miles away, which was disconnected. One farmer told me that he had to keep two cobs specially to do his milk traffic, and that the saving to him would be great. To keep down the expenses it was necessary to get the consent of the landowners, which I obtained, subject to the tenants agreeing, but before I had time to

approach the latter, they had a "round robin" signed by every one interested that it was not desirable to have any railway at all.

Wide gauge or none at all, some people say, therefore is it in many instances none at all. If the wide gauge can be made by any means, and rates are not proportionately increased and the district can maintain it, certainly have it; but the fact is often overlooked that the way to get a wide gauge is to start with a narrow one. Take an instance. Some four years ago I was consulted about a railway. They wanted a 3 ft. gauge with 40 lb. rails, but could not find the money. On receiving particulars of the traffic, I recommended a 2 ft. gauge with 25 lb. rails, which did the work admirably. The traffic has increased fourfold. Instead of two engines they have five, and if they want to lay a wider gauge now that the traffic has been proved financiers are to be found willing to advance the money. The best gauge for miniature main lines is undoubtedly 30 in.; 60 centimetres or 2 ft. makes a good "light railway," but when a larger engine than one with 8 in. cylinders is required for the work it is better to adopt the wider one, and an enormous amount of work can be conveniently done on it with 40 lb. rails and sleepers 2,112 to the mile. The cost of this per mile to-day would be about £800, and prices are high. On this railway, with curves 120 ft. radius, a six-wheeled coupled engine will haul 150 tons up a gradient of 1 in 100, or 75 tons up 1 in 50, and the speed may be 25 miles an hour. The weight of the long bogie wagons to carry up to 10 tons is about $3\frac{1}{2}$ tons. Just compare the dead load with that on our main lines in agricultural districts. The incline of 1 in 50 is, of course, a heavy one. In speaking of gradients few have an idea of the effect in hauling power. Once in Bohemia a contractor complained that an engine would not haul what I said it would on the level. I visited the site, a valley between hills, and it looked perfectly level. I was much surprised, but on testing it I found an incline of 1 in 57, which would reduce the load by 80 per cent., and only shows



60 C.M. GAUGE ENGINE, BY W. G. BAGNALL, LIMITED, STAFFORD, WITH 8 IN. CYLINDERS, CAPABLE OF HAULING 200 TONS ON THE LEVEL.

PASSENGER CARRIAGE FOR $29\frac{1}{2}$ IN. GAUGE RAILWAY, BY W. G. BAGNALL, LIMITED, STAFFORD.

how dangerous it is to trust to the eye in such matters. It is the usual custom to ask for an engine to haul a certain load on the level when in reality there is a considerable incline which reduces the load by perhaps two-thirds.

Perhaps the "Shap" is the best known gradient on our main lines on leaving Preston for the north. Take, for instance, 1 in 70, and the maximum load as compared with that hauled on the level would be, say 1,000 tons on level as against 250 tons on the incline, but in light railways much heavier gradients are adopted. About fifteen years ago, one Christmas Eve, I heard from a stranger abroad that a railway was wanted to take building material up a mountain and the gradients would be very heavy, and I was asked whether I would care to compete. I wired, "Will leave the day after to-morrow." When I arrived at the site I was told that foreign engineers had pronounced the scheme impossible. The length was $2\frac{1}{2}$ miles, the gradients 1 in 14, minimum curves which were absolutely necessary, 33 ft. radius, gauge 80 c.m. or $31\frac{1}{2}$ in. Well, of course, I had known engines go round such a curve, and up such gradients; but when one looked over the edge and saw some hundreds of feet of space, and above a precipitous mountain, it made one realise the responsibility. However, the contract was signed, and the goods sent off in due course. When the men were

INTERIOR OF SALOON CARRIAGE FOR $29\frac{1}{2}$ IN. GAUGE RAILWAY, BY THE OLDBURY CARRIAGE COMPANY.

ENGINE FOR 75 C.M. GAUGE, WITH 10 IN. CYLINDERS, BY W. G. BAGNALL, LIMITED STAFFORD.

laying the road, frequent cablegrams came beseeching me to withdraw the material, and so save the credit of myself and others concerned. My reply was, "Continue to lay rails; will come myself for trials." The whole installation was very satisfactory, not an accident occurred, except that one engine slipped backwards one morning, brake on the whole way down, 2½ miles, round the curves, and landed safely and unharmed on the quay. The engines weighed 13 tons, and hauled 14 tons under favourable circumstances, depending upon adhesion only. On two occasions I have worked on inclines 1 in 9, and in one instance 1 in 8, hauling empty waggons only.

The foreigners, with less money at their disposal, have undoubtedly pushed the light railway trade far more than we have, and as demand creates supply, many works have been started abroad to construct these lines on an economical basis. England was the pioneer of railway work, and, notwithstanding all that we have heard about American and other engines invading the home market, there can be no doubt that with the same facilities English work is preferred. But different countries have different fancies, and it must be owned, that

30 IN. GAUGE ENGINE, WITH LEADING TRAILING RADIAL AXLE, RUNNING ON A CURVE 90 FT. RADIUS, BY W. G. BAGNALL, LIMITED, STAFFORD.

whereas our designs are placed before the world with a decided disinclination to change, other makers, seeing their

PRESSED STEEL SLEEPER

chance, are prepared to make any alterations to suit the fancies of would-be buyers, whether it be in the shape of an elaborate cab which disturbs the balance of the engine, or by adding innumerable bright brass mountings which please the eye, at the sacrifice of the more or less unseen working parts. Still it is well, perhaps, in these days to "please" the customer, if it can be done without sacrificing the quality of the main work; but the best will in the end have its full acknowledgment, provided that the price is not unreasonable.

Many things that are seen on a main line engine can be dispensed with on a small one, and if "old hands" say, "You cannot call that a locomotive," the best reply is, "Find fault with the way it does its work if you can."

In this country, if we are to maintain our pre-eminence, we must bow to the inevitable, and without ever sacrificing good work for the sake of price, we can attempt, as far as possible, to meet the views of purchasers, though they differ very much from our own. My rule is to work to standard types, and add any fitments to meet local fancies, charging extra for same.

The question of design is exhaustive. That of outside or inside cylinders is one to be considered, as also a high or low centre of gravity. When I first commenced to make locomotives I preferred the inside cylinders, for it is natural that with all the work between the wheels the engine must run steadily; but, on the other hand, the parts are not always accessible, and the crank axle is liable to give way. There is not much objection to the outside cylinders in practice. Again, in a four-wheel-coupled engine I placed the tank under the smoke-box end of the boiler, to counterbalance the weight of the fire-box, and to keep the centre of gravity low. It certainly allowed for a deeper fire-box, and the boiler being placed a little higher, left more room underneath, between the frames, to attend to the parts. Contractors and others who have worked these engines have frequently asked for the same again, and

have been disappointed when told that experience has shown that high centre of gravity and saddle tanks are to be preferred. On a 2 ft. 6 in. gauge I once placed two engines, one with 10 in. cylinders, six wheels coupled, outside frames, side tanks, outside motion; the other with 11 in. cylinders, inside frames, inside motion, saddle tank, six wheels coupled, all compensated. It was an interesting experiment, and it will be noticed that the two engines differed in all essential points. Both engines ran round the curve of 120 ft. radius, but on comparison there was no doubt that the larger engine with the higher centre of gravity was easier on the road. It weighed 20 tons in working order, and was very steady when running at a fast speed. The rails weighed 36 lb. per yard. It will be noticed that the two bogie engines "Sodupe" and "C. F. A." have side tanks, this being the most convenient form for engines of this type.

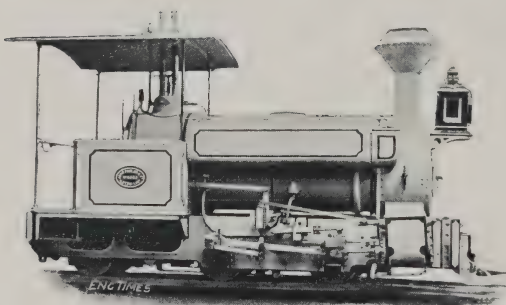
The mode of laying rails on wood sleepers is well known. There are many designs of steel sleepers, but in many cases they have a bad name, chiefly because the first designs were defective. Some were tried on the main lines in this country with flanges on the base. These rode on the ballast and caused trouble, whereas there should be no flanges or rounded surface for the sleepers to rest upon. The centre should be strong, to prevent buckling, and the ends slightly turned down, to retain the ballast. Therefore a rolled sleeper with the same section throughout is not to be recommended, and must have a good deal of unnecessary weight, whereas a pressed sleeper can be strengthened where desired by means of corrugations. Keys are very handy for fixing the rails into position, and by placing one on the inside instead of the outside of the rail, the gauge can be widened for curves by $\frac{3}{8}$ in. Then, again, by placing both keys inside, it can be widened by $\frac{3}{4}$ in. Punched out, corrugated chairs are preferable to riveted ones. When pressing, an incline of 1 in 20 can be formed on rail seat. The accompanying illustration shows the various points named.

HEAVY SADDLE TANK ENGINE FOR 2 FT. 6 IN. GAUGE, WITH 12 IN. CYLINDERS. WEIGHT, 20 TONS. BY W. G. BAGNALL, LIMITED.

To go into the various uses of the

light railway would exhaust your space, not to say your readers' patience. In plantations abroad thousands of miles are used of the permanent and portable (removable) type, and there are many designs to suit various conditions. No structural work of any important nature can now be carried out without its use, and no works can compete favourably with others unless the expense of moving articles about can be minimised by the inevitable light railway.

If I may be allowed to presume to speak of the future, I should say that serious overcrowding in large towns might be relieved, and that the health of the people might be much improved by a very simple scheme of light railways. Towns could purchase land outside, in healthy spots, where cottages could be built, and light railways could convey the workers to their shops, and back again. In this respect they would be conferring one of the greatest blessings on the working people of this country.



PORTABLE AND LIGHT RAILWAYS: THEIR DEVELOPMENT AND USES.

By H. C. DUBURGUET.

THE uses to which portable railways can be applied are almost innumerable, and such railways are especially serviceable where the work to be executed has to be done in a short time, as, for instance, in harvesting crops, and in contractors' jobs. The main principle of portable railways is the subdivision of loads so that each load can be easily handled and transported on a *light* line with *light* waggons.

A portable railway, to be thoroughly efficient, should embody the following: (1) Maximum of strength combined with a minimum of weight; (2) All the parts should be interchangeable; (3) The fastening of the rails to the sleeper should be made in such a way that it does not weaken either the rail or the sleeper; (4) Minimum of loose parts; and (5) No skilled labour should be required.

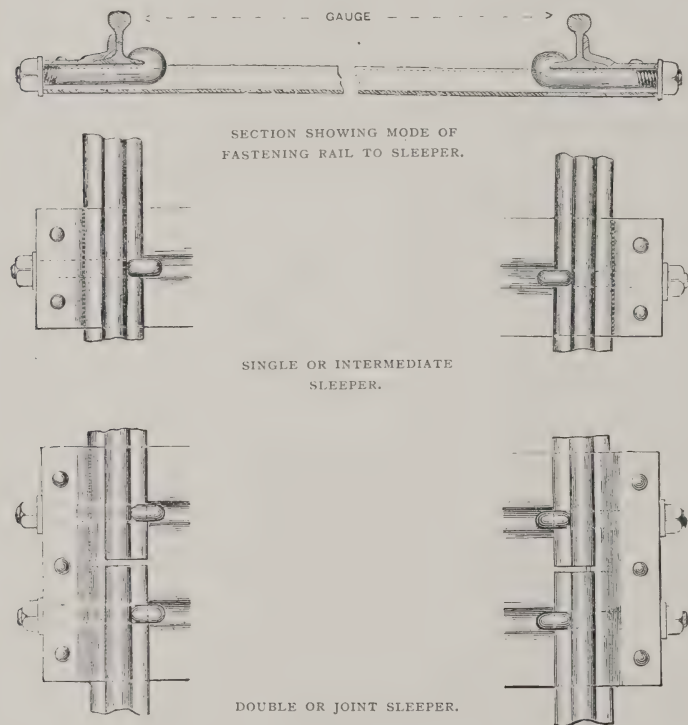
The portable railway described herein embodies the above advantages. The rails are fastened to the sleepers by means of steel chairs, into which the rail fits, and in which it is securely fastened by means of a clutch bolt. As will be seen by the engraving (Fig. 1), no holes are punched in either the rail or the sleeper where the weight comes on the rail. The rail joints are made by double corrugated sleepers, by which means the ends of the two rails are well supported. To combine lightness with strength, the sleepers have a deep corrugation in the centre, the joint sleepers having a double corrugation.

An endless variety of sections are manufactured both for the rails and sleepers, the outcome of the many applications of such railways. Whilst there are many variations in detail, the main principles remain the same, the details for each installation depending upon its own circumstances as regards the work to be done and the nature of the ground on which the line has to be laid.

For such ordinary industrial operations as are found on farms, brick and tile works, collieries, chemical sheds, lime works, iron works, and engineering shops, and, further, for pioneer purposes, in communicating small outlying towns and villages, also for construction purposes for railway and harbour works, light railways have been found of immense value.

During the winters of 1891 to 1894 the Leeds Corporation utilized the portable railway system with a view of employing unskilled labourers who during those severe winters were thrown out of their ordinary employment. The system was employed in the construction of new roads and improving public properties owned by the Corporation. In one case a hill was levelled and an adjoining hollow filled, involving the removal of about 85,000 cubic yards of earth.

For scientific expeditions and military purposes, the uses of such lines are well understood. Several scientific societies in charge of exploring expeditions in West and Central Africa have employed such railways. One of the difficulties which explorers have had to deal with is the transport of their light draft boats over or beyond the rapids. Boats constructed in compartments were taken out, but to carry these it necessitated a large number of natives, and progress was necessarily very slow, and left the explorers largely at the mercy of the natives. The accompanying illustration (Fig. 2) shows how boats were transported by natives, and the other (Fig. 3) shows the transporting by means of light railway with bogie carriages. Subsequently boats were made, and we believe answered the purpose very well, to be transported without being taken to pieces.



SECTION SHOWING MODE OF FASTENING RAIL TO SLEEPER.

SINGLE OR INTERMEDIATE SLEEPER.

DOUBLE OR JOINT SLEEPER.

FIG. I.

The Home Government war authorities, in the early times of the trouble in Egypt, realized the necessity of having immediate means of transport, and with this object in view they purchased an enormous plant of locomotives and bogie trucks for the use of the Suakim–Berber military expedition. The authorities in charge of the expedition considered that 18 in. gauge track would be the most suitable for them, it being imperative that a long mileage should be laid quickly, and the width of the road-bed minimised. The railway had rails about 24 lb. per yard, and was used for transporting military stores and ammunition. The engines used on this line weighed about twelve tons.

The economy effected between railway transport and road transport is considerable. In sugar-growing countries, for instance, the wear and tear of the animals is a very heavy item, which it is impossible to estimate. Then, again, in harvesting, time is of the utmost importance. The cane, once cut, must be transported to the mill with the least possible delay, so that it may be treated immediately it is in its richest condition. It has been estimated that the loss of time with road carts as compared with railway transport is four to one in favour of the latter. This is a very important item to consider, as should also be the large forces of men who are required to keep the roads in repair during the rainy season in tropical countries.

Portable railways are now very popular amongst planters in the Colonies: the principal sugar growers of the world find the system indispensable for rapidly harvesting and transporting the cane to the crushing mills. It will be understood that where the distance from the fields to the mill is considerable, say over one and a half to two miles, locomotives come into use; and where steam traction can be adopted, further advantages are secured, and economies effected. On a track, say, 2 ft. or 2ft. 6 in. gauge, enormous quantities of material can be transported. The construction of the line and rolling stock admits of easy adaptation to the contour of the country, so that irregular lines and sharp curves can be laid with practically no excavations or embankments.

For India and Burmah, and we suppose in most tropical countries, there are only two possible ways of getting timber from the immense forests, viz., by using elephants to drag the logs to the nearest water-way, or by the aid of a portable railway. An elephant, in spite of its large size, is (as all who have had to do with this animal know) a very delicate beast, and cannot be worked more than six hours per diem. Every few months it has to be rested entirely, and any elephant, to be of any good for forest work, costs at the very least 1,500 rupees (say £85). Each elephant represents, therefore, a capital which at any moment might disappear, owing to the animal dying or running away into the jungle, a case by no means of rare occurrence. It is therefore obvious that a portable railway is the best and cheapest method for forest work in these countries.

FIG. 2.—SKETCH SHOWING BOAT SECTIONS BEING TRANSPORTED BY AFRICAN NATIVES ON ORDINARY ROAD CARRIAGES.

Light railways are used as an adjunct to main line railways, as they can be used as feeder lines from outlying districts. Where a main line is not financially possible, a feeder line answers the purpose; and, moreover, is a source of revenue to the owners.

Feeder lines in India are now an established fact. The Indian Government, having recognized the benefits derived from such railways, are doing their utmost to encourage investors to lay as

many lines as possible in that country. Amongst the advantages offered by the Indian Government is the free use of one side of the high roads on which the line may be laid, and native wood sleepers have been supplied free to the promoters; such grants affecting an enormous saving to the owners of the feeder line in the first outlay.

As an example of such feeder lines, we might mention the Powyan Steam Tramway Co., which is to a gauge of 2 ft. 6 in., 31 miles in length, and runs between Kheri and Schahjahampur, Kheri being on the Rohilkund Kumaun Railway, and Schahjahampur on the Oudh and Rohilkund Railway, both of which are main lines. The traffic on that line is most varied: it consists of cereals, skins, wood for fuel, and, in fact, of all goods generally transported by railways, as well as for passenger traffic. The tramway has also the contract from the Indian Government to carry the mail. The line runs for the greater part on one side of the high road, crosses several rivers, and for about eight miles, on the Kheri side, passes through a forest (from which fuel is taken), away to a large sugar refinery and rum distillery, as well as to the Schahjahampur and Kheri termini.

FIG. 3.—SKETCH INTENDED TO SHOW THE SAME OPERATIONS (AS IN FIG. 2) BEING CARRIED OUT BY THE USE OF A PORTABLE RAILWAY AND BOGIE TRUCKS.

On plantation roads and provincial roads and tracks in the Colonies the resistance is very heavy, owing to the nature of the ground and the weather, in the rainy season such roads being frequently impassable.

A striking example of the advantages derived from a narrow gauge railway is the Tezpore Balipara Railway in Assam, India. Four or five years ago a bullock team carrying tea-chests, rice, etc., from the outlying tea-gardens to the river dock at Tezpore would, in the rainy season, which is the time for tea manufacturing, occupy twelve or fourteen days for a journey of only fifteen to twenty miles. Such work was a severe punishment to the animals, a large number of which died

FIG. 4.—VIEW OF A PORTABLE RAILWAY CONSTRUCTED BY MESSRS JOHN FOWLER & CO, (LEEDS), LIMITED.

every year, and there was considerable risk of damage to the cargo. The planters in the district, seeing the loss of time and money involved by this means of transport, amalgamated for the purchase of a small line of 2 ft. 6 in. gauge. The length of this line is about twenty-one miles, and at the present time two trains per day are regularly run in each direction with locomotives; a vast improvement on the old system, no one will deny.

Many more or less known installations of light railways may be referred to. Some have been termed "baby railways," with miniature trains in actual use; but these would come under the category of "hobbies" taken up by

FIG. 5.—GENERAL VIEW OF THE DARJEELING RAILWAY.

persons of sufficient wealth to indulge in such hobbies.

The industrial light railway and its uses will now be fairly well understood, but probably the most wonderful application of the light railway, and certainly a unique one, is the line known as the Darjeeling-Hymalayan Railway, joining Seliguri, the terminus of the Eastern Bengal Railway (a broad gauge Government railway), and Darjeeling, the sanatorium of Bengal, and 7,000 feet above sea level. This railway is about thirty miles in length, and laid to a gauge of 2 ft.; it is largely used for the transport of passengers from the plains of Bengal to the more bracing climate of Darjeeling, during the rainy season. The railway goes through the Darjeeling tea-planting district, and carries tea and stores, as well as all the machinery, etc., required for the tea-gardens. In such a brief article as this it is almost impossible to give an adequate description of the line, with its extraordinary zigzag route and shelving roadway. It is sufficient to say the line is run on the very edge of precipices, in some parts the rock having been cut away to form a shelf, on which the line is laid. The natural difficulties were successfully overcome, and the line has been worked for some twelve or fifteen years without an accident; and what is also important, has proved a financial success from the first. It is believed that the views of this line here shown have never been published before.

FIG. 6.—AN EXTRAORDINARY LOOP ON THE DARJEELING RAILWAY.

It will be seen that there is no comparison between the expenditure of tractive force required on a light railway as compared with road transport, and this saving becomes greater as mechanical power is adopted. When portable railways were first introduced they were intended to be worked by manual power the advantages were so striking as to at once call for the use of heavier trains hauled by animal power, and this, in its turn, led up to mechanical haulage; and now, wherever there is any distance to run, steam locomotives are employed,

and such engines are run successfully on lines of 18 in. gauge and upwards.

The diamond fields in South Africa are a well-known instance of the remarkable development of the light railway system. Small tubs were at first propelled by the natives; now, in every mine of any extent, trains of from twelve to twenty trucks hauled by steam are hurried in all directions by Liliputian engines. Eighteen inches gauge is a favourite one in those mines. Some of the companies, however, seeing the advantages of the system, have adopted 30 in. gauge; and have thus gained further economy.

Electrical engineers have now turned their attention to electricity as a motive power on such railways, and several small installations have already been made on the storage batteries system, and by the overhead trolley system; but this development can only be spoken of at present as in the experimental stage.

The development of the portable railway has necessitated the design and construction from time to time of almost every kind of vehicle, from a $\frac{1}{4}$-yard bucket truck up to a passenger car to carry twenty-four or thirty people, and intermediary stock of almost every description is now used. Largely as the system has been adopted, it is asserted that there are many industrial operations and transport requirements which could be successfully dealt with by narrow gauge railways. It must, however, be understood that this system is not intended to compete with the ordinary 4 ft. $8\frac{1}{2}$ in. gauge main line railway, but to be employed as an adjunct thereto.

FIG. 7.—ANOTHER VIEW, SHOWING THE ZIGZAG COURSE OF THE DARJEELING RAILWAY.

H C Duburquet

CAILLET'S MONORAIL.

By C. C. HOYER MILLAR.

IN the early dawn of the new century, when so much is being written on the subject of scientific locomotion, it seems an anachronism to call attention to a system of transport the maximum pace of which never exceeds five miles per hour. It was observed by Disraeli that the man who caused two blades of grass to grow where only one grew formerly, deserved well of his country; and in the same manner it may be claimed that an inventor who enables one man to do the work of two, or to increase either the pace or quantity of work formerly possible, is equally deserving of praise. Therefore, although the pace of transport by Caillet's Monorail system is certainly slow, yet inasmuch as it enables a man or an animal to move an increased load with the same expenditure of force, the system is of practical utility, and worthy of attention.

FIG. I.—VIEW OF CAILLET'S MONORAIL, USED FOR LIGHT TRAMWORK.

The principle of Caillet's Monorail system is traction by side leverage, and the cars or trucks have two or four wheels running in the same plane on a single rail. At first sight such a principle would seem to involve and perpetuate a side thrust, whereby the inner flange of the front wheel and the outer flange of the hind wheel would be kept against the rail. That this is not the case is readily proved by the

reflection that it is easier to cause a wheel to revolve along a smooth surface than to move sideways across it; hence the wheels move forward, and keep their proper position. The flat of the wheels is twice the width of the rails, thereby increasing the freedom of play; and as roller bearings are fitted to the interior of the hubs, friction becomes practically non-existent.

The car illustrated (Fig. 2) is the simplest in form, and shows at once the salient features both of system and method of construction. The sides of this car consist of movable flaps, which can be exchanged for panniers when light bulky material, such as hay, has to be carried. At the Birmingham Royal Show in 1898, on which occasion the system was first exhibited in England (and won the Society's silver medal), a car of this type was loaded with three trusses of hay, 56 lb. each, and worked by a boy of seven, who amused himself and numerous spectators for nearly an hour running the loaded car up and down the rail. Another car with flap sides was loaded with 6 cwt. of scrap iron, and, after the start, was propelled and balanced by several experimentalists with one finger, the line being, of course, on a dead level. These two examples fully demonstrate the absence of friction and ease of balance and propulsion.

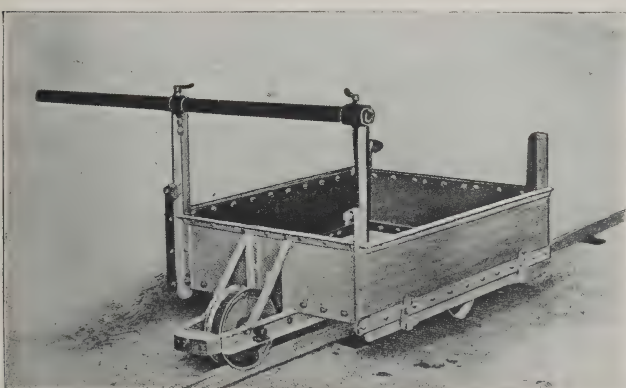


FIG. 2.—VIEW OF CAR OF CAILLET'S MONORAIL.

An extremely light section of rail is used, a 9 lb. rail being sufficient for all cars on two wheels with a load up to 15 cwt., and for bogie cars with a load of about 20 cwt. As the weight of the load presses directly down on the top of the rail, only sufficient strength is required to resist any permanent bending of the rail. For trucks loaded up to 30 cwt., a 12 lb. or 14 lb. section is employed, according to the amount of traffic per day. The 14 lb. section is also strong enough for trucks carrying a load of four tons, since all trucks for a load of over 30 cwt. are built on bogies, which by distributing the load over the rail obviate the bending tendency.

The *raison d'être* of Caillet's Monorail is not so much as a competitor with the light double-rail systems, as an intermediary between them and other forms of wheel transport (wheel-barrows, carts, etc.). It is essentially a system for small traffic, and the limit of its economical working varies from 75 to 150 tons per day, according to local conditions. Its chief value and economy are found where long distances have to be traversed, and the traffic amounts to only a few thousand tons per annum. In such cases the cost of cartage, mule packing, or native porterage can be reduced by as much as 80 per cent. A few concrete instances of this saving may be cited.

Only a few miles from London, where a daily traffic of ten tons has to be dealt with, an annual saving of £350 can be effected by Caillet's Monorail on the

present cost of cartage, which amounts to £450. In South America, where a mule train is now employed, the transport costs £3 10*s*. per ton for a distance

FIG. 3.—VIEW OF MONORAIL AS USED IN EGYPT FOR TRANSPORT OF LIME IN BAGS

which exceeds 100 miles. By using the monorail this cost can be reduced to 20*s*. per ton. As compared with native porters in Africa and elsewhere, who

FIG. 4.—SHOWS MONORAIL BEING USED FOR FARM WORK IN FRANCE.

carry loads of 56 lb. (*i.e.*, forty porters per ton), the saving amounts to 90 per cent., since by the monorail four men only are required per ton.

Even more important than the question of economy in working is the question of first cost. Here comparisons have to be made with the cost of a light double-rail system. Granting for the sake of argument the cost of the actual rails and fittings to be the same (as a matter of fact the sale price of the monorail is about two-thirds that of an ordinary double-rail system), the other outlays before the line is in working order have to be considered. First of all there is carriage, and here the economy may be taken at 50 per cent. Next comes the cost of preparation. The chief outlay in connection with a

FIG. 5.—VIEW OF MONORAIL IN USE AT A RANGOON SAW-MILL.

can be worked profitably on 10 per cent. of the traffic necessary to make a double-rail system remunerative.

On the other hand, greater clearance is required for the Monorail; but in a new country where land is cheap this is an unimportant matter. One man or animal is required for each truck or car, but the rolling stock is made in such sizes as will enable the maximum of work possible to be done by the man or animal. Speed of laying is an important feature of the Monorail, and actual experience in Mexico shows that forty men can clear, prepare the ground, and lay the line at the rate of $1\frac{1}{4}$ miles per day. A test for pace at Aldershot showed that a mile can be laid in four hours, the limit of pace being the time required for slipping each rail into the fish-plate placed on the end of the previous rail. The Monorail is the essence of portability, and requiring so

double-rail system arises from the necessity of giving equal support to both rails, and levelling a bed upon which the sleepers rest evenly.

Caillet's Monorail can be laid to follow the sinuosities of the ground, and requires no careful adjustment or regularity. The rails need not even be upright, and can be laid in a zigzag fashion without decreasing the efficiency of the system; in fact, it is waste of time to lay out tangents and regular curves. Each wheel is a bogie *ad hoc*, since the axles, instead of running in a fixed bearing, lie in a slotted groove, thus providing for play round a curve, as well as nullifying the effects of rough-and-ready laying.

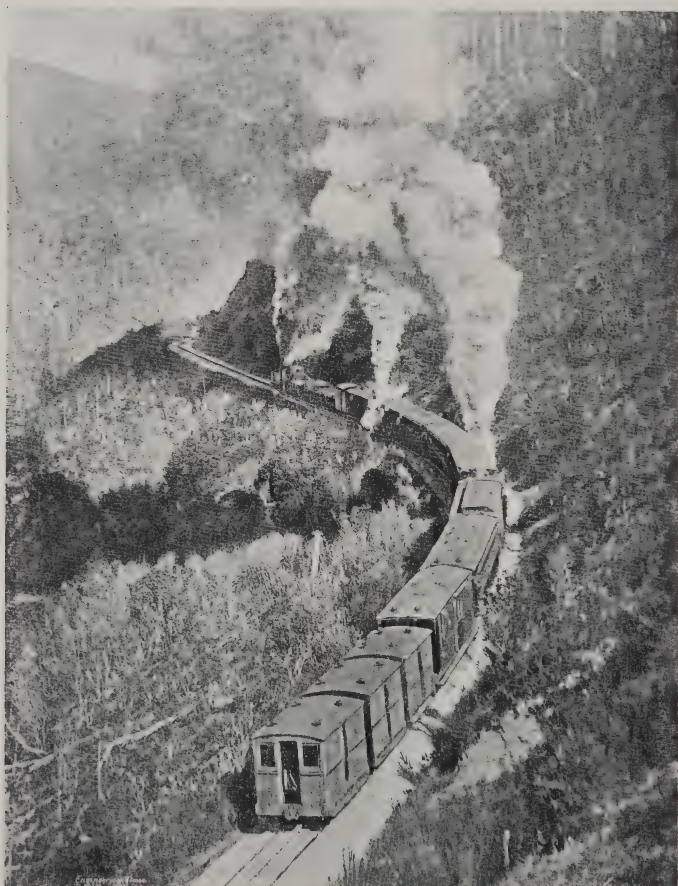
The cost of the requirements of a double-rail system and the cost of those of Caillet's Monorail are therefore very divergent, and, taking as a basis an undeveloped country where preparation is required, it may be stated that Caillet's Monorail will cost only 20 per cent. of any double-rail system, and

FIG. 6.—VIEW OF THE MONORAIL USED FOR THE TRANSPORT OF TIMBER.

little preparation entails a minimum of expense where a line has to be moved from place to place.

Although the system in its present form (for evolution has played its part since the original invention was made) is only a few years old, Caillet's Monorail is now working in many distant countries, and each month brings an increasing demand as its advantages become more widely known and appreciated. As a pioneer for aiding the development of new countries, its field is a wide one, and even at home there are many industries where its use would prove an economy as compared with existing methods. It has a sphere of its own, and seeks to work no harm to its older brothers, the barrow and cart, and its stronger brothers of the double rail. It can lighten the labour of man, and decrease the wear and tear of animals; and though it is no lightning express, its *rôle* is not without that dignity which comes from honest effort and useful function.

C. C. Hoyer Millar

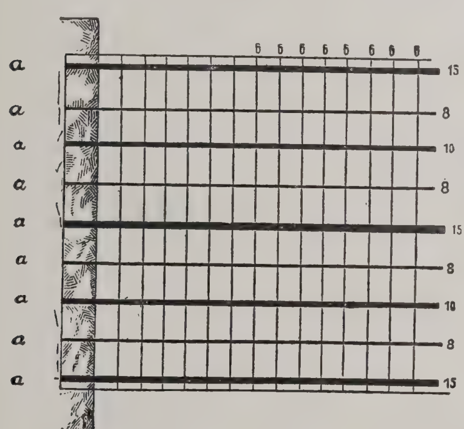


NEGOTIATING A STIFF GRADIENT ON A NEW ZEALAND RAILWAY.

ARMOURED CONCRETE FOR BRIDGE, TUNNEL, AND GIRDER WORK.

By H. C. WERNER, C.E.

HITHERTO concrete work in England has mainly been restricted to foundation work, retaining walls, reservoirs, etc., *i.e.*, to work requiring weight or bulk. The reason for this limited application is that ordinary concrete possesses great resistance against compressive stresses, but comparatively little with regard to tensile stresses. But during the last twenty years great progress in concrete constructions has been made on the continent. In the seventies, J. Monier, of Paris, gave the first impulse to armoured concrete work by strengthening concrete structures by inserting wrought iron rods, thus obtaining great strength and elasticity. This system (which he named "Travaux en ciment avec ossature en fer"), the so-called Monier system, was taken up in France, Belgium, Switzerland, Germany, Austria, etc., and found to be very suitable for the making of level or arched ceilings, circular tanks, light road-bridges, etc., etc. Fig. 1 as an example shows the way Monier arches are made. Longitudinal rods *a*, *a*, *a* are laid down at about 3 in. distance, then $\frac{1}{4}$-in. rods are laid across at a similar distance, the whole thus forming a sort of network with meshes of 3 in. by 3 in., which is afterwards embedded in concrete. The sectional area of the longitudinal rods is calculated according to the strength required; the cross rods, which only serve to equally distribute the load, have $\frac{1}{4}$ in. diameter. A theory was worked out by Mr. M. Koenen, of Berlin, and published in 1887, showing how to calculate the strength of concrete and iron in armoured concrete floors and ceilings, arches, tubes, and circular tanks. The firm of Messrs. Wayss & Freytag, at Neustadt (Germany), having recognized the importance of



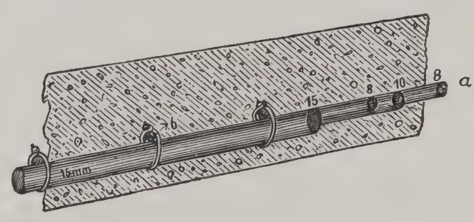


FIG. I.—DIAGRAM SHOWING DETAILS OF MONIER ARCH.

FIG. 2.—ARMOURED CONCRETE GIRDER BRIDGE OF 40 FT. SPAN.

this method, spent large sums for making exhaustive tests with various armoured concrete structures, and as they were assisted by scientific research, the theory of the new system was so improved that we are enabled now to obtain an accurate estimate of the value of the two materials, iron and cement, when acting in combination in any structure. The theory is now not limited to arches, slabs, tubes, and circular tanks, but is applicable for calculating girders, joists, and columns made of armoured concrete. The system is extremely suitable for all sorts of railway structures, as bridges, culverts, subways, goods sheds, reservoirs. To illustrate what is done we give a few examples of armoured concrete work carried out on the continent. Fig. 2 shows an ordinary beam-girder-bridge, of 40 ft. span. It consists of two armoured concrete girders 7 ft. 3 in. centres, each 3 ft. 1 in. deep, and 1 ft. 8 in. wide, covered with a flooring $5\frac{1}{2}$ in. thick, having a total width of 10 ft. The rails are laid on ordinary cross sleepers and ballasted road.

Illustration No. 3 shows an armoured concrete road bridge of a span of 145 ft., thickness of arch 16 in. at the crown.

Extensive application of the armoured concrete system has been made in covering the Vienna Metropolitan Underground Railway, as illustrated in Fig. 4, the span, varying from 28 ft. to 38 ft., total depth of construction 3 ft. 5 in. at 7 ft. centres, carrying 2·4 tons per square metre. A great portion of the line has been arched in, having a span of 33 ft., thickness of arch at the crown 9 in., and at the haunches 13 in.

The great advantages claimed for this system of construction are:—

Great strength and stability.
Elasticity and pliancy.
Economy in construction.
Indestructibility.
Non-corrosion.
Costly painting dispensed with.
Architectural effectiveness, and
Beauty of design.

The reason armoured concrete can be more quickly constructed is that iron or steel rods are always at hand, whereas to obtain special girders or columns of iron or steel is a comparatively expensive, tedious, and slow process, and necessitates a large body of skilled workmen, besides the loss of available section due to riveting.

This, however, is not the case in an armoured concrete girder or column, as the tensile portions are formed of iron or steel rods, and the concrete encasing it securely holds the rods together, and forms the compressive portion. In fact, a girder in armoured concrete is fixed in position before special iron or steel girders would be half finished; so that work in armoured concrete can be carried out much more expeditiously, and with proportionately fewer men.

In building construction this is particularly noticeable; large blocks of warehouses of seven and eight floors, supported by armoured concrete girders and columns, have been erected in five months, whereas it would have taken, at the very least, three times as long to erect the same in the usual manner with iron girders, columns, and joists.

The iron or steel rods used being entirely covered by the concrete, are thus permanently preserved, whereas under ordinary conditions, exposed iron or steel girders, etc., deteriorate with rust, and require periodical coating with paint or other preservative.

It is now well known that exposed iron or steel in floors and columns of buildings when attacked by a serious fire is nearly as perishable as wood, because the metal itself does great damage by twisting and expanding with the heat. Armoured concrete is the only desirable fire-proof construction, as the concrete securely insulates the metal, and prevents the heat affecting it.

FIG. 3.—ARMOURED CONCRETE ROAD BRIDGE OF 145 FT. SPAN.

A great feature in the numerous

engineering and architectural works built on the armoured concrete system may be seen in the beautiful designs of bridges and buildings of various kinds, showing how easily this class of work lends itself to decorative effects.

Having now dealt with the great advantages of the system, it is necessary to discuss and to refute the objections most commonly raised against it, especially by engineers who understand ordinary concrete, but have not had experience in armoured concrete work. Firstly, it has been contended that the adhesion of iron and concrete, on which the whole of the theory of the system is based, is destroyed in case of great changes in temperature. Owing to the high coefficient of expansion of iron, the rods embedded in the concrete would become disunited, thus causing the failure of the structure. This objection appeared very plausible, and could only be refuted by experiment. Extensive fire tests were made by leading engineers in 1886 at Breslau and Cologne, with the result that armoured concrete structures may be considered to be absolutely fire-proof.

M. Bonniceau, a French engineer, has carefully studied the question of expansion of various building materials: granite, marble, concrete, sandstone, etc., and has published in the "Annales des ponts et chaussées" the coefficients of expansion for these materials, being the result of long scientific tests. According to this publication, the coefficient of expansion of Portland cement concrete varies from 0,0000137 to 0,0000148 for 1° Celsius. The coefficient of expansion of iron is 0,0000145, or in other words the coefficients of expansion of iron and of cement concrete are practically identical. Thus it has been proved by theory as well as by practical trial that the changes in temperature do not affect the adhesion between iron and concrete.

Another objection raised against this system was the alleged inability to resist continuous vibration and impact from heavy concussions. This has been refuted by experience, which has shown that armoured concrete ceilings carrying high-speed engines for upwards of twenty years remained intact and in good condition. Railway bridges are constructed in armoured concrete with excellent results, notwithstanding the vibration these structures are subjected to by moving loads. Most interesting experiments were made in 1898 at Vienna by the military authorities with an arch of 43 ft. span and thickness at the crown of 8 in. (see Fig. 5). A set of Ecrosite cartridges sufficient to destroy a solid stone arch of the same span and of 3 ft. thickness at the crown, was put across the arch, the explosion causing only a partial injury, the rest of the arch remaining intact. In the moment of explosion the crown of the arch showed a deflection of about 8 in., but returned immediately to its normal position, thus demonstrating the enormous elasticity of the material. It required a double set of cartridges, sufficient to destroy a similar stone arch of 6 ft. thickness at the crown, to break the arch; but nevertheless the portion that had been subjected to the first explosion still retained its original form (see Fig. 6).

Further, it has been alleged that it is impossible to form a correct theory on the combined value of iron and concrete. To refute this we will give a short explanation showing how carefully the present theory has been worked out. In order to obtain correct results, sufficient attention must be bestowed on the relations of the coefficients of elasticity of the two component materials. This proportion to be α. To calculate the stresses generated in a given section by the influence of

the Moment M, we have to multiply the sectional area of the iron with α, and for the increased sectional area thus obtained, we have to locate the position of the centre of gravity and the Moment of Inertia. According to Navier's theory of deflection we have then:

Maximum stress for the concrete at taining this, and after numerous experiments, it has been found that for the mixtures of cement and sand generally used for armoured concrete and for average stresses, the coefficient of elasticity can be assumed to be 200 tons per square centimetre or 1,250 tons per sq. in., so that $\alpha = \frac{12500}{1252} = 10$. This

FIG. 4.—ARMOURED CONCRETE COVERED WAY, VIENNA METROPOLITAN RAILWAY; SPAN = 38 FT.

a distance y from the neutral axis $\sigma y = \frac{Y.M.}{T.}$, and for the iron: $\sigma y = \alpha. \frac{Y.M.}{T.}$. The coefficient of elasticity for iron is 2,000 tons per square centimetre, or 12,500 tons per sq. in. The coefficient of elasticity of concrete cannot be given so accurately, as it depends upon the proportions of sand and cement, upon its setting, and moreover this coefficient varies a little with the stresses, so that it decreases when the stress per unit is increasing. Considerable difficulty has been experienced in ascer- factor does not materially influence the result of the calculations, so that it does not make a great difference if it is not quite accurate.

The calculation of the iron rods is made under the assumption that the concrete does not possess any tensile strength, and that the iron has to take up all the tensile stresses. On the other hand, the tensile stresses which in reality exist in the concrete must not exceed its limits of elasticity in order to avoid cracks. Experience has shown that breaking strain of concrete mixed in the

FIG. 5.—VIEW SHOWING THE EFFECT OF A FIRST ECROSITE EXPLOSION ON AN ARMOURED CONCRETE ARCH OF 42 FT. SPAN.

FIG. 6.—VIEW SHOWING EFFECTS OF SECOND EXPLOSION.

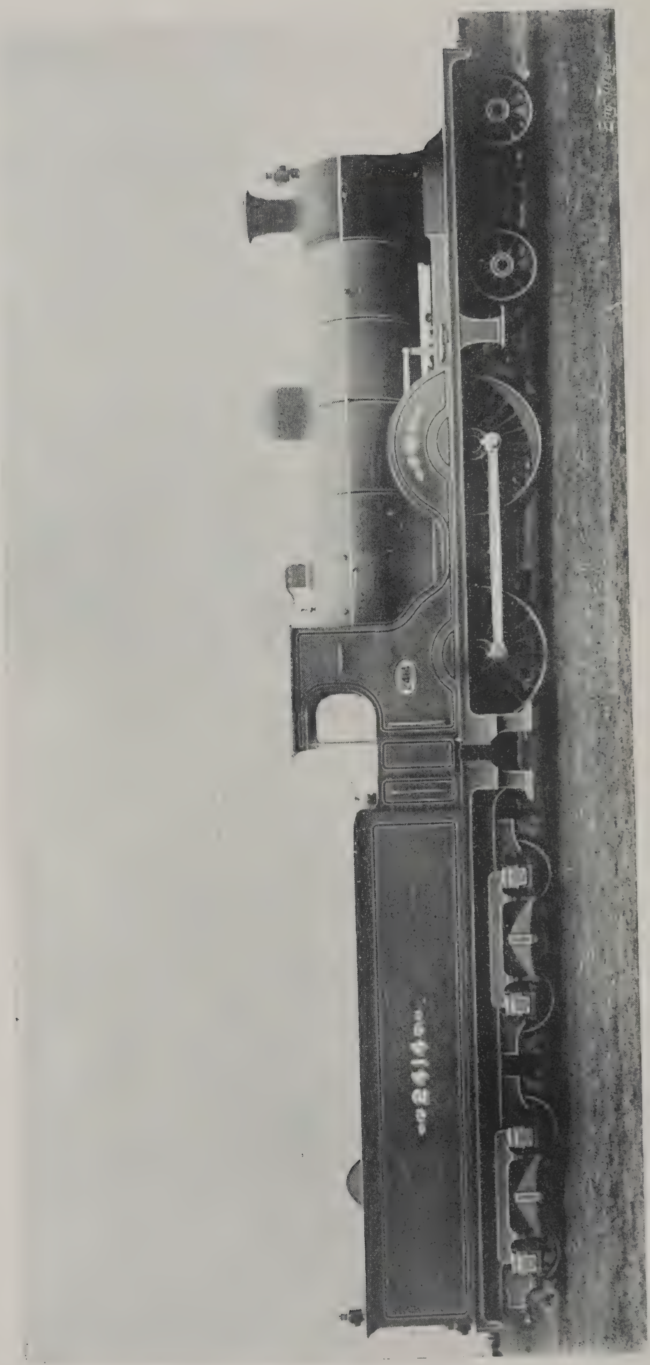
proportions used for armoured structures varies from 200 to 300 kilogrammes per square centimetre, or from 2,750 to 4,100 lb. per sq. in. Thus the safe load of such concrete can be safely assumed at 30 kilogrammes per square centimetre, or 410 lb. per sq. in. The safe load may be increased even to 500 lb. per sq. in. when the exact value of the maximum stresses can be calculated to a nicety, and when the structure is not exposed to vibrations caused by moving loads.

Experiments made with a view to ascertain the tensile strength of concrete showed that it is much higher than it is generally believed, varying from 410 to 680 lb. per sq. in. This refers to armoured concrete only, not to ordinary concrete. It is a fact still awaiting explanation that the combination of iron and concrete has such a favourable influence on the tensile strength of the concrete, but nevertheless such is the case.

Summing up the result of these experiments, we see that the safe loads for armoured concrete are as follows:—

Compression
in concrete = 410 to 550 lb. per sq. in.
Tension in
concrete = 410 to 500 lb. per sq. in.
Iron rods = 6·5 to 7·0 tons per sq. in.

The relation between the coefficients of elasticity of the two component materials $\alpha = 10$. On this base the static calculations for our structures are made, and the practical results obtained have demonstrated the truth of the theory.



EXPRESS PASSENGER LOCOMOTIVE FOR THE BELGIAN STATE RAILWAYS, 4 FT. 8½ IN. GAUGE. DESIGNED BY MR. J. F. M'INTOSH, LOCOMOTIVE ENGINEER CALEDONIAN RAILWAY. BUILT BY MESSRS. NEILSON, REID & CO., GLASGOW.

MISCELLANEOUS ARTICLES ON RAILWAY AND TRAMWAY ENGINEERING.

RAILWAY CARRIAGE LIGHTING BY ACETYLENE GAS.

THE extraordinary illuminating power of acetylene as compared with coal-gas naturally led to endeavours to adapt its uses to the lighting of railway carriages. We believe it was the Acetylene Illuminating Company who in the United Kingdom first made experiments in this direction in the year 1895, shortly after the introduction of carbide of calcium manufactured on a commercial scale in electric furnaces erected by that company.

In 1896 experiments were made with undiluted acetylene compressed in cylinders on the London and North Western Railway, a composite coach being lighted by it with magnificent effect; two one-foot burners being employed in the compartments, and one half-foot burner in the lavatories.

Mr. F. G. Worth, the managing director of the Acetylene Illuminating Company, having ascertained that pure acetylene when compressed under two atmospheres would explode if a pipe connected to the receiver were heated to the temperature necessary for the decomposition of acetylene, these experiments were at once discontinued. Whilst they were going on, Mr. C. A. Park, of the London and North Western Railway, made some experiments with admixtures of compressed oil-gas and acetylene, which gave very satisfactory results. But these were also discontinued, because an Order in Council was issued bringing compressed acetylene, either alone or mixed with other gases, under the Explosives Act, unless it could be shown to the satisfaction of the Secretary of State that such gases could be so compressed without danger.

Experiments were also carried out by Mr. J. A. F. Aspinall for the Lancashire and Yorkshire Railway Company, particulars of which were given by Mr. Henry Fowler in a paper read by him before the Institution of Civil Engineers on March 15th, 1898.

A most thorough investigation of the dangers alleged to exist in connection with the use of acetylene was made by Mr. H. Gerdes, the chief engineer to Messrs. Pintsch, of Berlin, and his results were communicated to the Berlin Institute of Mechanical Engineers on December 1st, 1896, with the result that it was proved that the employment of a mixture of 30 per cent. acetylene and 70 per cent. oil-gas for railway carriage lighting involves no danger whatever, because the increase of temperature will never be sufficient to burst the receiver. The investigations of Mr. Gerdes and the practical experiments in this respect, which were in particular carried out in the presence of Director Borck, of the State Railway Management of Berlin, led to the adoption of the admixture of compressed acetylene and oil-gas for lighting railway carriages on the Prussian railways, and we believe that from 6,000 to 9,000 tons of carbide are annually employed for

generating acetylene for the purpose of such admixture.

In the latter part of 1897, an application was lodged at the Home Office by Mr. F. G. Worth to sanction such a mixture in England under the ordinary railway carriage cylinder pressure of 10 atmospheres. The safety of the mixture, and of mixtures considerably richer in acetylene, was completely established by a series of tests carried out by Mr. Worth in the presence of the Home Office officials, and in consequence, by an order of the Secretary of State dated March 28th, 1898, a mixture of oil-gas with 20 per cent. of acetylene is allowed to be used at a pressure not exceeding 150 lb. to the square inch.

Experiments were subsequently carried out by the Acetylene Illuminating Company for one of the railway companies in the neighbourhood of London, which were extremely satisfactory. Practically little or no progress, however, has been made with this form of lighting in the United Kingdom, the various railway companies probably considering that there was not sufficient economical advantage to justify a modification of the systems actually employed. But it would seem probable that these views may be changed, especially if there be a reduction in the price of carbide.

With carbide of calcium at from £21 to £22 per ton delivered, acetylene will cost about £1 16*s.* to £2 per 1,000 in the holder, and taking 200 cubic feet as being mixed with 800 cubic feet of oil-gas, the cost of the acetylene will be, say, 7*s.* 8*d.* The compressed oil-gas costs from 6*s.* to 12*s.* per 1,000. With oil-gas at 8*s.* per 1,000, 800 cubic feet will cost 6*s.* 5*d.*, so that the total cost of 1,000 cubic feet of the enriched gas will be 14*s.* 1*d.* But as the illuminating volume of the mixture is double that of the plain oil-gas, there is an economy of 1*s.* 11*d.* per 1,000. As the oil-gas is dearer, the saving will be greater, and *vice versâ*, so that with cheap oil-gas the addition of acetylene would not pay at the above price of carbide. With oil-gas at 6*s.* 6*d.* per 1,000, and carbide at the above price, there is practically no difference, but the advantages accruing from the use of acetylene would make the mixture more desirable than the plain gas.

Amongst the advantages are these: That the cylinders would last for double the length of time they would with the oil-gas with the same charge, and there would not be so much formation of liquid hydrocarbons due to compression with consequent revaporising when the pressure is reduced, thus causing the inequality in the illuminating power.

The value of oil-gas and the mixture of oil-gas with acetylene have been determined photometrically in an ordinary railway carriage lamp at angles below the horizontal, and show that the addition of 20 per cent. of acetylene doubles the illuminating value of the oil-gas. Whether pure acetylene compressed will ever be authorised in this country remains to be seen, but we are informed that it has been decided in America to equip several entire trains with the light produced from pure acetylene compressed in cylinders at 150 lb. These cylinders and the high pressure pipes are constructed in such a way that in case of a car catching fire the seams fuse at 260° C., and the pressure is relieved long before the detonating point of the gas is reached. The lamps are especially made to take their air supply from without, and to get rid of the hot products of combustion without heating the gas supplied. With the exception of Germany, however, few railway companies abroad have adopted on a large scale the use of acetylene, preferring doubtless to wait until many of the troubles connected with the smoking of

the flame have been overcome. It may fairly be said, however, that none of these troubles now exist, and that the purification of acetylene is more thoroughly understood, so that we may look for a fresh movement in this direction, especially with a reduction in the price of carbide.

If the danger of compression of undiluted acetylene is successfully got over, there would be a wide field for it, as a cylinder of acetylene would last three times as long as one of oil-gas, and give a far better illumination.

Many attempts have been made to fit railway carriages with small automatic generators, and experiments are still being pushed in this direction; but the trouble of frequent cleaning and recharging makes it doubtful whether such a system will prove successful as against the simple method of compressing acetylene in cylinders.

We understand that the Acetylene Illuminating Company are carrying out experiments with compressed acetylene dissolved in various materials saturated with acetone, and in various materials without acetone. We believe that they have demonstrated that acetylene so compressed is not explosible; but the company have not yet carried their experiments far enough to be able to form an opinion as to whether there would be any economic advantages to the railway companies in this form of lighting.

FIG. I.—VIEW OF THE LANGEN MONORAIL RAILWAY SUSPENDED OVER THE RIVER WUPPER.

THE LANGEN MONORAIL.

IN other parts of this number the proposed express monorail electric railway to be constructed between Manchester and Liverpool, and Caillet's Monorail—one the most ambitious, and the other the most modest of monorail schemes—are dealt with. Here we propose giving a few particulars and illustrations of another novel single-rail railway.

In our illustration (Fig. 1) we show a section of the Barmen-Elberfeld Railway suspended over the River Wupper. This novel railway is the invention of the late Herr Eugen Langen, and is a little over nine miles in length, divided into twenty stations. In his, the original experiments, Herr Langen

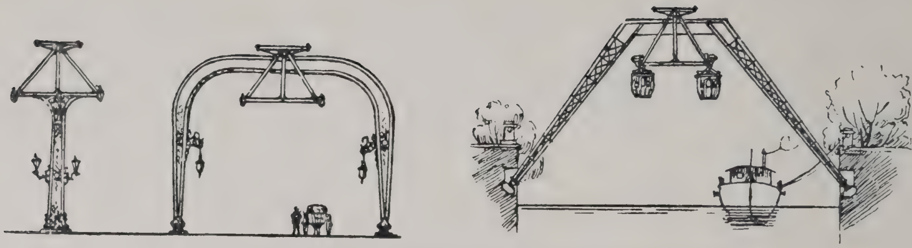


FIG. 2.—SHOWING FORMS OF SUPPORT ON THE BARMEN-ELBERFELD RAILWAY.

used a suspended carriage on the two-rail system, with which he secured a speed of only $7\frac{1}{2}$ miles an hour. In his next attempt, in which he used a single rail, a speed of $15\frac{1}{2}$ miles an hour was obtained. The line runs partly over the River Wupper, as shown in our illustration, and partly over streets and roads (see Fig. 2). As will be seen from our illustrations, the railway has up and down lines, which are supported by inclined posts over the river, and curved posts over the high roads.

The carriages, each of which is capable of carrying 50 passengers, are suspended from two-wheel trucks, two trucks to each car, running on the T rails, and the form of suspending arm is said to be such as to prevent derailment. Between the two axles on each truck is a 36 h.-p. 500-volt electric motor, current being taken from a contact rail by a slip shoe. An electric brake and a pneumatic Westinghouse brake, as well as hand brakes, are provided, and it is said that a speed of

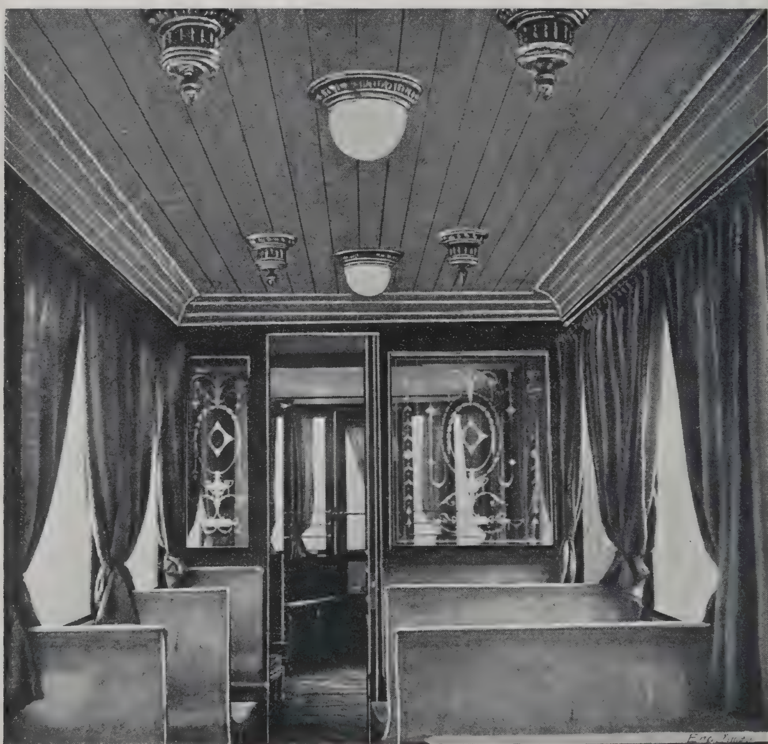


FIG 3.—INTERIOR OF CAR—BARMEN-ELBERFELD RAILWAY.

25 miles an hour can now be easily attained. The view of the interior of a car (Fig. 3) shows the comfortable passenger accommodation. Fig. 4 shows a section of a short line exhibited at the Paris Exhibition.

One of the greatest objections to this form of railway is said to be that in negotiating curves the carriages swing outwards to a very uncomfortable extent. This swinging in pendulum fashion is said to take place on some of the curves on the Barmen-Elberfeld line to an angle of 25 degrees from the vertical. This railway can only be regarded as an interesting curiosity by engineers, and it is possible that it is the first and last of its kind to be built.

FIG. 4.—LANGEN MONORAIL AND STATION EXHIBITED AT THE PARIS EXHIBITION, 1900.

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THE DEVELOPMENT OF TRAMWAY CARS.

IN view of the rapid introduction of tramways into this country, it is interesting to study the progress which has been made in America during the last 28 years in the development of tramway cars. The two illustrations which accompany this paper represent American types of cars of 28 years ago and to-day. The first of the illustrations shows a car built in 1873 for the Market Street Line in Philadelphia; the second one represents a style of car, of which many hundreds have been built, and are building for the Union Traction Co. of the same city. Both types of cars come from the workshops of the Brill Company. Those familiar with American tramway history will recognize the fact that the latter company is not only the successor and present owner of the old Market Street Line, but practically controls all the tramway lines in the city of Philadelphia.

Twenty-eight years ago horses and mules were the sole propelling power for tramway cars the world over, if we except a half-a-dozen so-called "dummy lines" in the United States. These dummy lines were so few in number and so exceptional in every respect, that they hardly need be considered.

The load of the car and its weight were therefore limited by the strength of a pair of the average animals available. In those days the 3-horse team

FIG. 1.—THE STANDARD AMERICAN CAR 28 YEARS AGO.

with the animals abreast was unusual in America, and the "tow horse" attached to an eye in the crown piece was the only means for overcoming sharp grades. The comparatively small power available made it always necessary to keep the weight of the car down below 5,000 lb., the Market Street cars weighing about 4,700 lb., although some of the lightest tramcars did not exceed 4,100 lb. They were nominally 16 ft. long in the body, and had a seating capacity not usually exceeding 22 persons. Every item in construction was as light as possible. The roof was of the pattern known in the shops as the "bird cage," but spoken of in a more dignified way as the "Bombay Roof," the ventilator extending only a portion of the length. The ventilator was practically set down upon the curved car-lines of the roof which ran through it. The Market Street order in '73 was for a single sample car, but an order for 50 of the same type followed shortly after. This sample car, shown in the engraving, was handsomely

FIG. 2.—THE MODERN AMERICAN CAR.

decorated inside and out. It is curious to remember that the oil painting decorating the outside panels represented an attack by Indians upon a lever hand car on one of the Pacific railroads, an incident which had happened within a year. The roof itself has completely changed its form, and the monitor deck now extends the whole length of the car body. This improvement was introduced by the predecessors of the J. G. Brill Co. They made the monitor high and wide, frequently decorating the glass in its sides. This increase in size has added materially to the comfort of the car both summer and winter, and providing much better ventilation than formerly. It has the additional advantage of greatly strengthening the roof, making it better able to support the trolley pole.

Contrasting the car with those the Union Traction Co. is purchasing to-day, we find that the new cars have 28 ft. bodies as against 16; ten windows on a side instead of eight. The width, too, is increased; then the car was 6 ft. wide at the sills, and now it is 7 ft. $8\frac{1}{2}$ in. In the horse-cars all windows dropped; in the new cars a decided innovation has been made, and the windows are stationary and locked in place from the outside by a special form of lock and key; the sashes are, however, interchangeable, so that there is no delay or difficulty in taking them out of storage and putting them on the car, as in warm weather they are removed so as to make the car completely open. The seats are of spring cane with reversible backs, and seat 40 persons in all. The shape of the side differs somewhat from the old horse-car style, and instead of depending solely upon panels, ribs, and posts for strength, a truss plank is introduced which is screwed upon every post. In addition to this there is an outside truss rod going from bolster to bolster, as well as a low truss rod inside of the car. The seats and posts are so spaced as to bring each seat between two posts. Although not shown in the engraving, these cars are provided with portable vestibules, and the brake handle and shaft comes far enough inside so as to permit its easy operation. While these cars are mounted upon double trucks of the 27-G type, they have their sills within $30\text{-}\frac{11}{16}$ in. of the rail, making the distance to the step $15\text{-}\frac{7}{8}$ in.; the step itself has a 13 in. riser, and the platform is 8 in. below the floor of the car. All the platform openings are closed by Brill folding gates. The illumination is

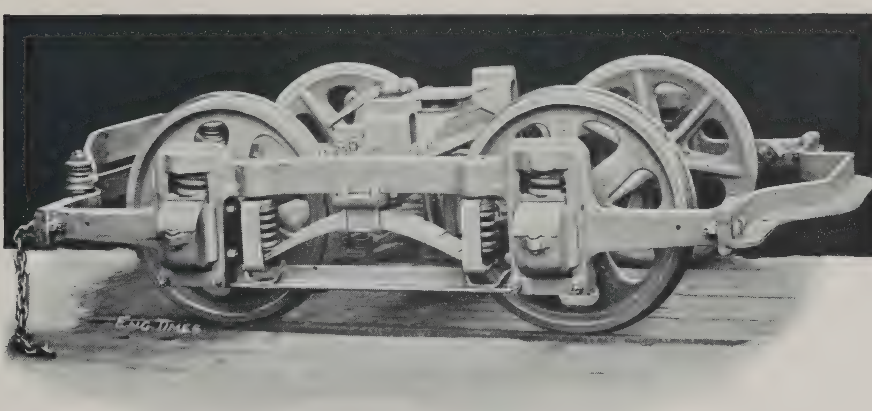


FIG. 3.—THE LATEST TYPE OF TRUCK, IN USE BY THE UNION TRACTION CO. OF AMERICA.

in marked contrast with that of the horse-cars, which at most had three dim kerosene lights, one at each end, and a larger one occasionally with a double burner in the centre of the ventilator deck. The new cars are wired for ten lights, three 3-light clusters and one light under each hood; when in operation the rear light only burns. The hand-pole for supporting the hand-straps inside of the old-style car is retained, but the brackets are increased in length, so as to bring them out towards the aisle. This is for the purpose of keeping those who stand well away from passengers who are seated. In these cars there is a notable effort to give the greatest possible seating capacity, even at the expense of some standing room. The propelling power is not far from 160 h.-p. The speed in Philadelphia is certainly three times as great as it was 28 years ago, and, in the suburbs, 20 miles an hour, or even 25, is not unheard of; the old horse-cars rarely exceeded five.

The change in taste relative to the decoration of street cars has been very marked in the last 28 years. Scroll work on the exterior is rarely seen; the paintings which often decorated interior panels have disappeared entirely. The form of the roof has changed, and the advertising panel occupies most of the space formerly used for decoration. Three-ply veneer is now universally used for head linings, and in the new Union Traction Co cars it is finished in natural colours with a few lines of striping to relieve the plainness of the wood. The "car-line finish," as it was called (in which the car-lines themselves show, and the roof boards finished in natural colours, usually with a combination of light and dark woods), has disappeared except in the most common styles of car. Colours outside have not been materially changed; white, cream colour, and the lighter yellows have been found to stand better than any others, and as they give better protection to the wood than darker colours, they have been very generally retained. Perhaps the most marked change of all is seen in the running gear; the horse-car with its small weight, short length, and slow pace was mounted upon four wheels, whose $2\frac{3}{4}$ in. axles seem like wires compared with those at present used. The springs, usually eight in number, carried the car body in the simplest manner: it practically floated on the springs, and was capable of a limited amount of motion in all directions. It was a very easy form of running gear.

When the street car became self-propelled, a new principle had to be developed before it was possible to make the electric car a success. Former experiments with steam on the street railways had given little general information on this point, since most of them had been devoted to the development of a dummy hauling the ordinary street car as a trailer. The fathers of electric railway propulsion first sought success by putting the motors on the platforms of horse-cars. This, of course, caught the commercial eye; to hang the propelling power on the platform or on the body of the horse-car so as to change from one style of propulsion to the other, with no expense beyond that required for the electric apparatus, was a good idea, but impracticable. It was tried by all the early electricians and by all of the roads that first attempted the installation of electricity. Its failure was sudden and complete. Just before the introduction of electricity, the J. G. Brill Co. had been experimenting with a self-propelled steam-car for street railways. In these experiments they found that it was necessary to go back to the locomotive principle, and provide a substantial frame to carry the machinery; they also found it necessary, both for mechanical reasons and for

questions of economy and repairs, to make the car body and the locomotive two different structures. Long before the electric men had dreamed that they could not apply electricity directly to the old horse-car bodies, the Brill Co. were preaching both in season and out the necessity of the independent frame and running gear which was afterwards known as the truck. The expense, prejudice, and the hope of a cheaper solution of the problem for about three years prevented this change from obtaining any hold among street railway men. As time went on nearly every electrical engineer who was experimenting in electric street railway propulsion, after his first failures with motors on the car body or platform, came to the Brill Co. for some form of separate truck. The truck which the Union Traction Co. have finally adopted as giving them generally the best results with four motors per car is what is known as the No. 27-G, a metal frame, equalized, swing-beam truck with a short wheel base and three sets of springs for carrying the load.

Instead, therefore, of four light wheels beneath the short body, the modern car used by the Union Traction Co. has eight wheels disposed in two trucks, each of which, when complete, weighs nearly as much as the old horse-car. By reason of the easy motion which they impart, and the freedom with which they move from side to side with small irregularities of the track without imparting such motions to the car body, they are extremely easy on the flanges, and the wear and breakage is consequently very small. The equalization is so perfect that the load on each wheel is practically constant under all conditions. The combination of these two features renders the truck the safest of any in use, and high speeds can be maintained on tracks otherwise impracticable. For the past two years the Union Traction Co. have had in operation several hundred "Eureka" maximum traction trucks under the old four-wheel electric cars, which they cut in half and spliced them, making the bodies two windows longer. This truck fits the peculiar conditions of narrow bodies on short curves, and is the only type of truck that meets the requirements of one motor per truck on narrow bodies. It has at the same time the advantage of 30 per cent. increased adhesion on the driving wheels, while it does not increase the height above that of a four-wheel car.

It must be said in favour of the old-fashioned car bodies that they were built like carriages rather than like steam cars, and their endurance was something phenomenal. Often after 10, 15, or even 20 years of service as horse cars, they were mounted upon electric trucks, and saw 6, 8, or even 10 years of severe electric service before being finally discontinued.

The question is often asked why not go a step further and put on 30 or 36 ft. bodies, and make a proportionately greater gain in the number of passengers which one equipment and two men can handle? The reason why 28 ft. may be looked upon at the present time as the maximum length, and why longer cars are not practical, is found in the nature of the service. One conductor cannot attend successfully to a greater number of passengers than a 28 ft. body will hold. If there are frequent stops he has to depend on people standing on the rear platform to tell him when the passenger is safely on or off, because he cannot traverse the whole length of the car to see every one that gets on or off and properly collect his fares. This increases the danger of accidents. High speed is essential to the success of the electric road, and as speed is cut down the profits diminish. Where a man has a very large car and avoids accidents, he must of necessity take more time than

would be otherwise necessary in seeing his passengers on and off. This increase in the time slows the car and reduces the profit. Cars of 32 ft. bodies on several of the Jersey roads are obliged to loaf on many trips in order to give the conductor time enough to get all the fares, and the numbers missed at such time shows conclusively that the car has exceeded the profitable length. When stops are made at every street corner, the 28 ft. body is quite as long as will be found economical for the street railroads.

THE WESTINGHOUSE ELECTRIC CONDUIT TRAMWAY.

THE question of electric conduit street tramways is one of great interest and importance at the present time, seeing that it is the most suitable means of providing rapid transit over our city streets, and that the necessity for some such means of traction is daily becoming more and more pronounced. So far as this country is concerned, practically nothing has been done beyond the usual talk of various municipal bodies. "The city will have its tramways, and they shall be the best of any; the workman shall have his 'halfpenny-any-distance' ride," and so forth; then the matter is allowed to lapse for a certain length of time, and the workman ceases to look forward to the boon which the grandfatherly council promised. The question is, in this way, alternately taken up and passed aside. It is pleasing to note, however, that in the case of electric traction, the municipal see-saw is gradually getting a more pronounced bias in favour of making a start at the actual installation of a system, and no doubt we shall, all in due course of time, see a modern electric conduit street tramway in this country.

Such dilatory methods would be to a certain extent justified if the work entailed in tramway construction necessarily involved entirely new principles and methods. Such work is long past the purely experimental stage, and is to be found in actual successful operation in many places.

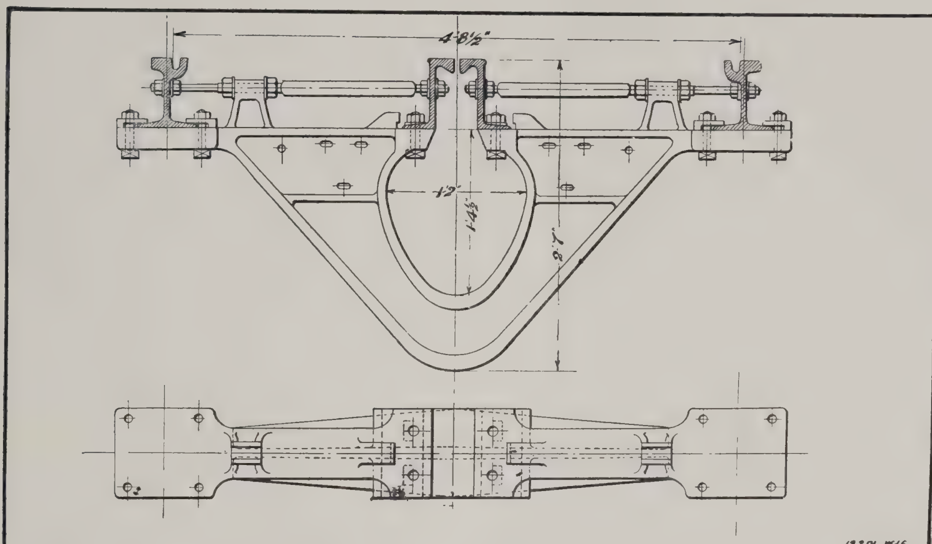
Probably no branch of electrical engineering can boast a history which shows such perseverance as that of the electric conduit tramway. Numerous expensive failures were the rule for many years, but success was eventually attained, and several examples of electric conduit tramways have now been in actual and efficient operation for some years past.

The large number of conduit systems tried and proved failures were sufficient to show up definitely certain points in conduit design which were absolutely fatal to success. The principles to be avoided are: flexible electric conduit conductors, pedestal supports for the conductors, less than four inches clearance between the lower edge of the plough and the conduit floor, inaccessibility of insulators, independence of conduit and track-rail structures, the use of wood or other perishable materials as part of the track or conduit construction. Of course the principles of general design also evolved to a certain extent from the early experiments, such as the form and strength of yokes, slot-rails, shape and material of duct, etc.

As representing modern practice in electric conduit tramway construction, it will be of interest to consider, as far as space will permit, the construction of the Westinghouse conduit, in which is embodied the outcome of previous conduit work.

The illustrations, Figs. 1, 2, and 3, show clearly the general style of construction, and also the principal dimensions. It will be seen that the centre slot principle has been adopted in the Westinghouse conduit, and that the

cast-iron yokes are of the "extended" type, that is, the track-rails are carried on extensions of the yoke castings. The upper face of the yoke, between the slot-rail seats and the track-rail seats, a strong lug is cast, to which all rails are



FIGS. 1 AND 2.—WESTINGHOUSE ELECTRIC CONDUIT YOKE: TYPE 2E.

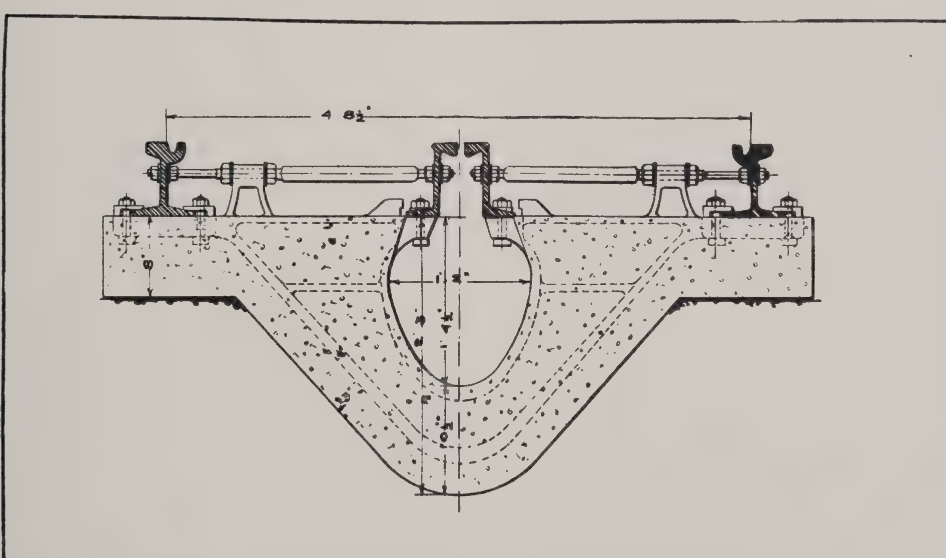


FIG. 3.—WESTINGHOUSE ELECTRIC CONDUIT: SECTION AT YOKE.

slot-rails are bolted to the upper jaws of the yokes, which are placed 5 ft. apart, centre to centre, and the track rails are bolted to the yoke extensions. Tie-bars are arranged as shown; on the tied by bars from the rail webs; an additional pair of tie-bars between the slot-rails and track-rails are also fixed midway between adjacent yokes. This form of construction has many points to

recommend it. The yoke itself will resist a lateral pressure applied at the rail centres of over 43,000 lb. before the slot-rails yield $\frac{1}{16}$ in. Experience has shown that pressures equivalent to about 20,000 lb. applied at the rail centres often occur in practice. The arrangement of metal in the yoke is such as to combine the maximum strength with the minimum weight. By carrying the track-rails on the yoke extremities, the most rigid track construction is secured, any settling of the ground is followed by the whole track work, uniformity of gauge is preserved, no undue strains are thrown on either track-rails or slot-rails, which are so tied together that the stresses occurring are distributed and taken up by the rigid casting of the yoke itself. The placing of the rail joints on the yokes ensures the smoothest of running tracks. Experience has shown that for electric traction the form of yoke independent of track-rails, that is, without extensions, is altogether unsuitable; some success has been gained by using independent yokes where the slot rails also form one of the track-rails, but this method has many disadvantages, such as the great width of the slot and the intricate and expensive special work at crossings and turn-outs. The form and size of the conduit below the yokes is shown in Fig. 3. It is of concrete, and a continuous smooth duct of the section shown runs the full length of the system.

The electric conductors are of T-section iron rail hung from insulators fixed at intervals of every third yoke. The insulators are of earthenware, and are each fixed in a handhole, so that they are easily accessible by lifting a small cover. It is essential that conductors should be suspended from above, since it is practically an impossibility to keep either pedestal or side bracket insulators and supports clean; accumulation of mud and moisture are bound to earth and short-circuit the mains, and the cost of cleaning such supports must certainly be very high, since each pedestal would have to be cleaned frequently, and by hand. Insulators above the conductors are the only types which have been successful in practice. Another important advantage in the use of top insulators is that the cleaning of the conduit can be efficiently and rapidly effected, since the conduit way is maintained quite clear through its length. The conduit is of the best shape for rapid and efficient drainage, and its depth is sufficient to allow for a few inches accumulation of mud below the lower edge of the collecting plough. The problem in conduit design is not exactly how to prevent mud and water entering the duct, but rather to arrange matters so that deposits of mud do not interfere with the working of the system, and that water, even to the extreme of floods, may be drained away more rapidly than it can enter. The slot-rails are provided with drip edges on the inner side of the upper flange, so that the water is allowed to fall directly to the bottom of the duct, passing between and away from the conductors and insulators.

This short description will be sufficient to show the care which has been exercised in the design of the Westinghouse conduit, and to show that in it the excellent reputation of Westinghouse engineering work is well sustained.

EXPRESS LOCOMOTIVE & TENDER FOR THE DUTCH RAILWAY COMPANY.

WE illustrate in one of the plates given with this issue the Standard Express Engine in use on the above-named important system. A large number of engines of this type have been constructed during recent years by Messrs. Sharp, Stewart & Co.,

Limited, of Atlas Works, Glasgow, and they are employed in working the fast and heavy continental mail traffic *viâ* the Hook of Holland (in connection with the Great Eastern Railway Company's Harwich route), and the express service between Rotterdam, the Hague and Amsterdam.

The engine is of the usual British inside cylinder class, with an "Adams" bogie (the side play controlled by a special arrangement of laminated springs) and four wheels coupled. The cylinders are placed close together, with the steam chest, of triangular form, lying over and between them. This arrangement allows room for extra long journals in the driving axle.

The bottom of the fire-box is sloped and carried backwards over the hind axle, a large fire-grate area being thus provided, the nature of the coal used making this more than usually necessary.

The boilers are of steel, with copper fire-boxes, and tubes of iron or steel.

The following are the principal dimensions:—

Cylinders.	
Diameter	18 in. by 26 in. stroke.
Boiler.	
Diameter	4 ft. 6 in. (11 ft. long).
Fire-box.	
Outside length	7 ft. 8 in.
Tubes (213).	
External diameter	$1\frac{5}{4}$ in.
Heating Surface.	
Fire-box	111 sq. ft.
Tubes	1106·5 ,,
Total	1217·5 ,,
Grate.	
Area	22 sq. ft.
Wheels.	
Bogie	3 ft. 3 in. diameter.
4 Coupled	6 ft. $7\frac{3}{8}$ in. ,,
Wheel-base, fixed	9 ft.
,, total	22 ft. $9\frac{1}{2}$ in.
Weight.	
In working order	47 tons.
Tender.	
Carried on six wheels	3 ft. $7\frac{1}{2}$ in. diameter.
Tank.	
Capacity of	2,800 gallons.

DRUMMOND'S PATENT WATER TUBES FOR LOCOMOTIVES.

On most railways, in this and other countries, there is a constant tendency towards increase in the weight of trains, but the limit imposed by the loading-gauge (particularly in this country) prevents the necessary corresponding increase in the dimensions of the engines. To meet the constant increase of the train loads on the London and South-Western Railway, and to overcome the difficulty regarding the maintenance of steam power with heavy express engines, Mr. Dugald Drummond has designed and patented the arrangement of cross-water tubes shown in Figs. 1, 2 and 3, and fitted on the locomotive illustrated in one of the plates herewith. Thirty locomotives thus fitted have already been made by Messrs. Dubs & Co., of Glasgow, for the South-Western Railway.

As may be seen, these tubes are arranged in two nests, extending across the inner fire-box, and to promote the circulation of water, the one nest is inclined in an opposite direction to the other—the inclination being at the rate of 1 in 11. The nests consist respectively of 36 and 25 solid drawn steel tubes, $2\frac{3}{4}$ in. outside diameter and $\frac{1}{8}$ in. thick, expanded into and beaded on the fire-box side plates. Doors are provided at both ends of each nest, to give easy access to the tubes for inspection or renewal. Stays, secured to the inspection doors by the screwed thimbles and running right through the tubes, support the sides of the shell.

The heating surface of the fire-box (normal) is 148 sq. ft., and that of the water-tubes 165 sq. ft.; the introduction, therefore, of these tubes more than doubles the heating surface at its most efficient part, viz., the fire-box. The increased circulation of the water, where the heat is most intense, promotes evaporation, while it prevents

formation of scale. The advantages claimed are, therefore, "Increased evaporative power and economy of fuel consumption." The arrangement also acts as an almost perfect spark arrester.

Engines of the class exhibited have been employed for nearly three years, with perfect freedom from trouble, on express trains weighing 390 tons, exclusive of engine, tender, luggage, and passengers, and the boilers are capable of maintaining a full head of steam with such trains. The saving in consumption of fuel per mile, as compared with engines of same class not fitted with water tubes, is stated to average 5 lb.

The principal dimensions of the London and South-Western Railway locomotive, illustrated in one of the plates, are as follows:—

Cylinders.	
Diameter	$18\frac{1}{2}$ in. × 26 in.
Wheels.	
Coupled	6 ft. 7 in.
Bogie	3 ft. 7 in.
Tender	4 ft. 0 in.
Boiler.	
Diameter at front	4 ft. $5\frac{1}{8}$ in.
Fire-box.	
Length	6 ft. $9\frac{5}{8}$ in.
Width	3 ft. $6\frac{1}{8}$ in.
Depth at front	6 ft. $8\frac{9}{16}$ in.
Depth at back	6 ft. $2\frac{9}{16}$ in.
Tubes.	
In barrel:	
280 of $1\frac{1}{2}$ in. outs	10 ft. $9\frac{1}{2}$ in. long.
In fire-box:	
61 of $2\frac{1}{2}$ in. ins	3 ft. 7 in. long.

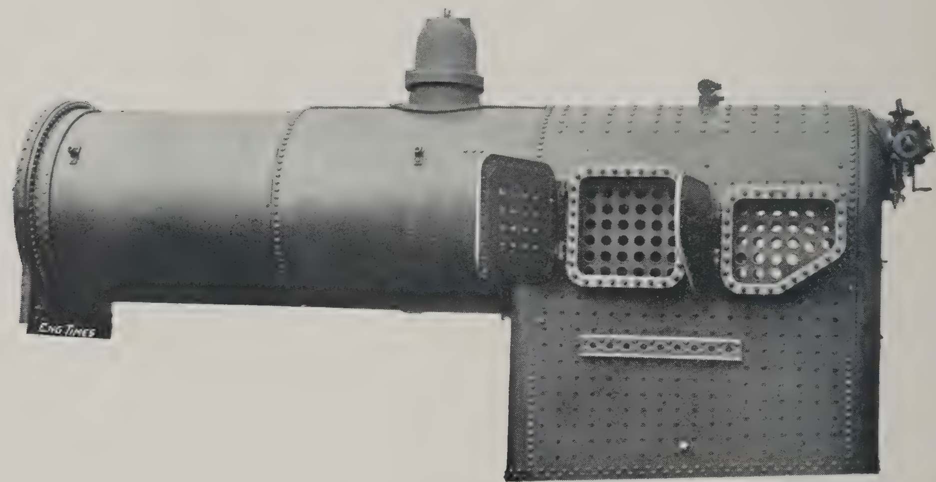


FIG. I.—VIEW SHOWING DRUMMOND'S PATENT WATER TUBES, AS FITTED TO A LONDON AND SOUTH-WESTERN RAILWAY PASSENGER LOCOMOTIVE.

Heating Surfaces.

Tubes in barrel	1,187 sq. ft.
Tubes in fire-box	165 sq. ft.
Fire-box	158 sq. ft.
Total	1,500 sq. ft.

Grate area	24 sq. ft.

Working pressure of boiler, 175 lb. per square inch.

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FIRELESS STEAM LOCOMOTIVES.

TRANSPORT still offers a large field for constructive improvements. A remarkable novelty are the fireless locomotives for railroads, a speciality of Messrs. Orenstein and Koppel, Bush Lane House, Cannon Street, London, E.C. The economical importance of the fireless

locomotive consists in the circumstance that it does not itself produce the high-pressure steam by the combustion of fuel, but draws the necessary supply of steam from a stationary working boiler. Its superiority therefore consists in its considerably greater safety in working. The locomotive, having no fire of its own, cannot emit sparks, which consequently removes the risk of ignition. A further advantage of this engine is that there is no risk whatever of an explosion, as the steam supplied to it cannot but decrease in pressure during work. As with this engine there is also an absence of all smoke, it can appropriately be used for shunting in enclosed places, workshops, etc.

FIG. 2.—DIAGRAM SHOWING INCLINATION OF A FRONT NEST OF TUBES.

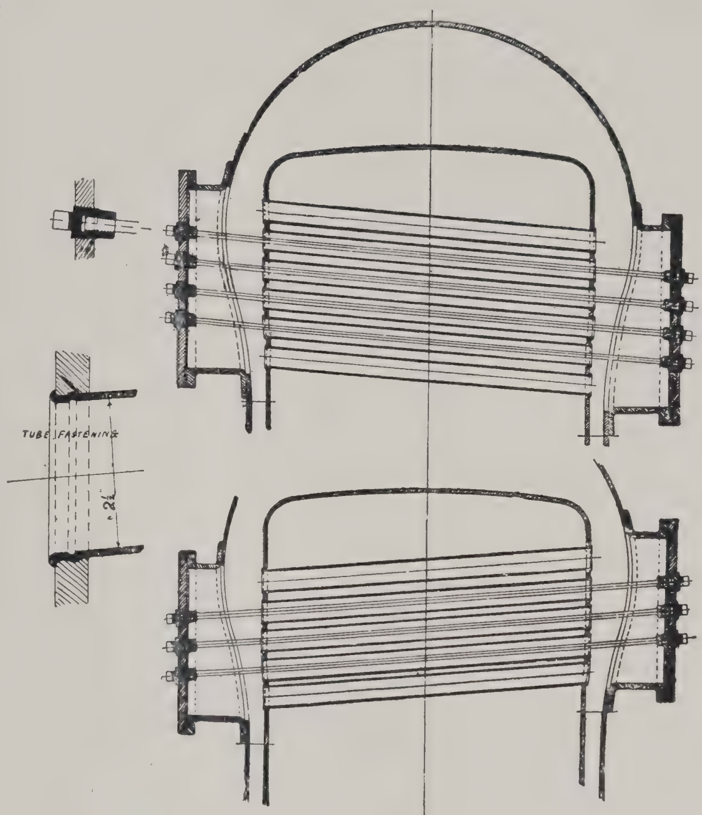
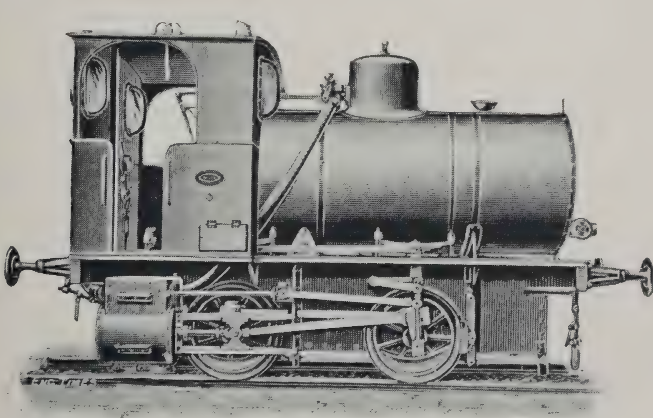


FIG. 3.—SHOWING INCLINATION OF BACK NEST OF TUBES.

The engine does not require to be manipulated by a skilled engineer, as, there being no firing, the constant attention to the boiler—an important feature with all other engines — is unnecessary, and the engine can be worked by any ordinary workman.



A FIRELESS STEAM LOCOMOTIVE.

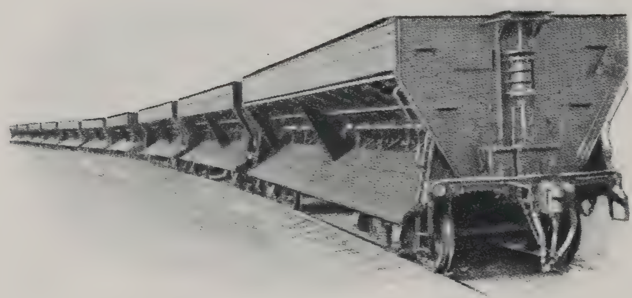
A number of these engines have already been supplied to different works on the Continent, where they are giving every satisfaction. Messrs. Orenstein and Koppel have had an engine in use at their own works in Spandau, near Berlin, for over six months, and we are, through their courtesy,

enabled to give the following data regarding the cost of working this engine :—

	£	s.	d.
Cost of engine, £600			
10 per cent. Depreciation ...	60	0	0
Coal consumption for furnishing steam to the engine, 105 tons at 20s. each	105	0	0
Lubricating and cleaning materials	15	0	0
Repairs and maintenance ...	7	10	0
	187	10	0
Wages for workman, 1 man ½ day = 150 days 3s. each ...	22	10	0
In all per year	£210	0	0

Or 14s. per working day.

Whereas there were previously required for shunting 30 men at 3 hours = 90 hours, or per year 2,700 days at 3s. each—£405, or 27s. per day.



A TRAIN OF "GOODWIN" CARS.

This constitutes a decreased expenditure of 13s. per day, or £195 per annum, or a saving of almost 50 per cent. in favour of the fireless locomotive.

It must also be taken into consideration that this saving steadily increases in the course of time, as interest and depreciation for the engine are reduced from year to year. With one filling with steam the fireless shunting locomotive working at Spandau has covered a distance of about 12 miles.

This new type of locomotive is entirely different from the fireless locomotive of Honigmann, of which formerly so much was heard. The latter, as is well known, was worked by a solution of soda, whilst in the Lamm-franq system used in the present case merely over-pressure water is used to procure the steam.

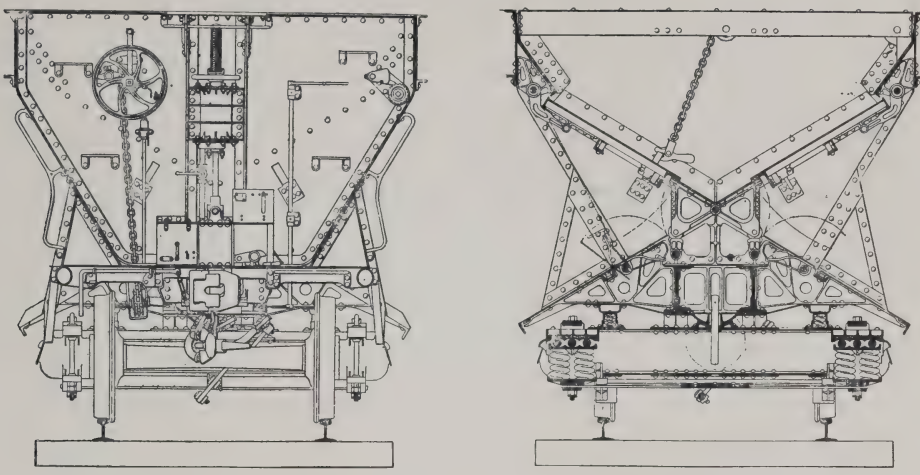
Messrs. Orenstein and Koppel have up to now principally built one size of these engines, and are so able to give quick delivery for same. The dimensions of this Standard type built for a gauge of 4 ft. 8½ in. are :—

Diameter of cylinder	17 in.
Length of stroke	16 ,,
Diameter of wheel	35 ,,
Wheel base	68 ,,
Weight empty	10½ tons
Weight in working order ...	13½ ,,
Utmost steam pressure obtainable	130 lb.
Water in boiler, about	6,000 ,,

The tractive force depends, of course, upon the pressure existing and the amount of steam with which the cylinders are being filled. If, for instance, an engine of above dimensions would work with a pressure of 100 lb., the cylinders being filled with about 25 per cent., the tractive force would be about 3,100 lb. and running at a speed of 10 miles an hour the engine would have a capacity of 60 h.-p.

THE "GOODWIN" CAR.

IN our illustrations we show the "Goodwin" car, now so extensively used in America for railroad making, *i.e.*, ballasting, filling, road raising. Its special features will be readily understood from the illustrations. The floor is an obtuse V, either side of which can be opened by one man in a few seconds with the aid of compressed air or steam, the necessary machinery to utilize which is fixed to each car. This car is an

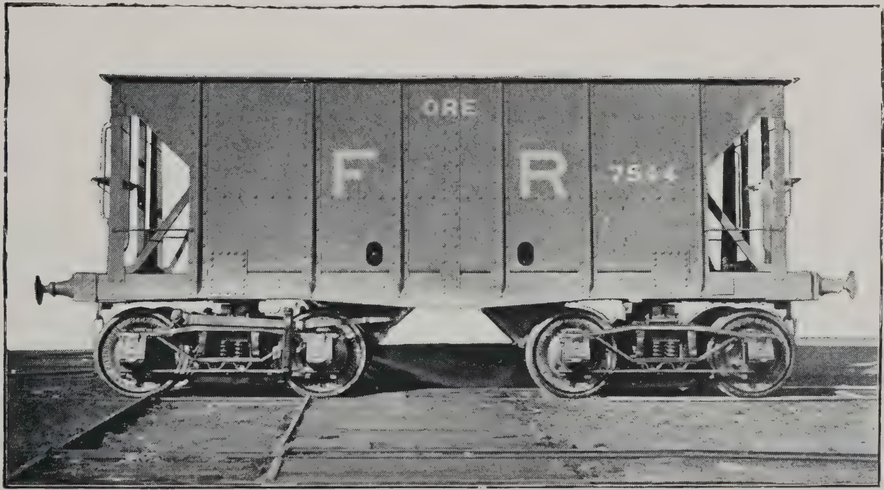


VIEWS SHOWING THE CONSTRUCTION OF THE "GOODWIN" CAR.

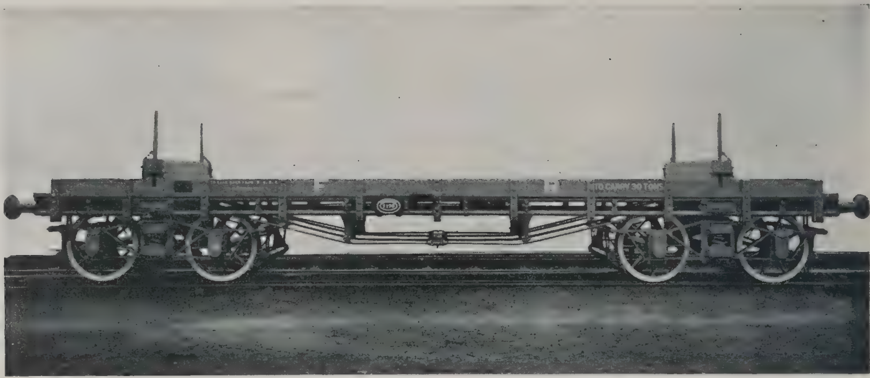
enormous labour-saver ; in the old way, namely, with the shovel, it takes on an average seven men about three-quarters of an hour to unload twenty tons, double which work can be done in a few seconds by one man operating this car. Further, it can be discharged on one, either, or both sides at the same time, and also between the rails on either side; and another point is that any of these operations can take place with perfect safety while the train is running at any speed. The car, if discharged while running, will spread the load from five to thirty feet from the track, and the width of the "spread" can be regulated by the speed of the train.

BOGIE WAGGONS ON THE FURNESS RAILWAY.

ONE of the chief features in connection with the goods and mineral traffic of the Furness Railway is the large number of bogie waggons used by the company, some of which are 40 ft. long, and whilst only weighing 10 tons, are capable of carrying 30 and 40 ton loads, the ratio being as low as 20 per cent. of



THE NEW TYPE OF BOGIE ORE WAGGON, FURNESS RAILWAY.



30-TON BOGIE WAGGON, FURNESS RAILWAY.

dead weight to carrying load. Most of these waggons are used for carrying rails from the various steel works on the system. Recently bogie waggons have been introduced of pressed steel for carrying iron ore, each waggon carrying 45 tons of ore from the mines and docks to the ironworks around Barrow, the tare of these waggons being only 12 tons 15 cwt., so that the tare is 22 per cent. of the gross weight.

A LIGHT INSPECTION CAR FOR RAILWAYS.

A NEW departure in the matter of railway appliances is found in the "Hartley and Teeter" Light Inspection Car, which is manufactured by the Light Inspection Car Co., of Hagerstown, Indiana, U.S.A. This car is a cycle-built vehicle, with four flange wheels to adapt it to an ordinary railway, and it has for some time been in use both in America and on the Continent, and for the last two years on some of the English and Irish railways, and also on the Colonial railways. It can be easily lifted on and off the rails by one person (see Fig. 2), and dispenses with the necessity of using a locomotive for inspection purposes, resulting in a saving of from £3 to £5 per day in inspection expenses. The cost of the new vehicle is about the average price of the ordinary road cycle; it can be driven at a speed of from fifteen to twenty miles an hour, and will easily run up a gradient of one in twenty. It is adaptable to any gauge, affording opportunity for visiting and inspecting any portion of the road to which attention is required.

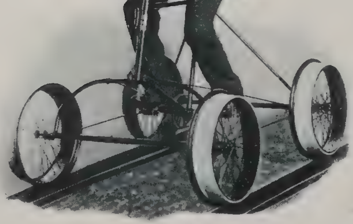


FIG. I. "HARTLEY AND TEETER" LIGHT INSPECTION CAR.

These cars have been found useful in the traffic department of railways, when it becomes necessary to visit stations without the usual formality of a train notice; they are also used on extensive colliery sidings by some of the largest colliery companies.

The car may be propelled by one or two sitters, as required, and an adjustable seat can be attached to the

FIG. 2.—SHOWING A RAILWAY INSPECTION CAR BEING LIFTED FROM THE RAILS.

FIG. 3—ENGINEER INSPECTING LINE—BELFAST AND NORTHERN COUNTIES RAILWAY.

front for the inspector (see Fig. 3). It can be easily handled, loaded, and carried in the guard's van when necessary, and its weight does not exceed 75 lb.

When using it, a permanent way inspector is afforded a much better opportunity of examining and reporting on the road than is possible from the footplate of an engine. It is so constructed that it will pass with safety the most complicated points and crossings at junctions.

The car can also be used with great advantage in cases of failure in train tablet working, which occurs frequently, often dislocating the traffic seriously on long sections, and causing great delay to passenger trains. When a failure occurs, the pilot man can speedily cover the distance from point to point, instead of having to walk it, which he is now often compelled to do. The car can be kept in the station-master's office on long sections, so as to be available at a moment's notice. It is approved of by some of the leading railway engineers in this country, and several contracts have been entered into for supplying these cars to the Crown Agents for the Colonies. They are also used on a number of English and Irish railways. The sole British agent is Mr. John Milliken, of 2, Belfast Bank Chambers, Belfast.

EXHAUST STEAM AND RE-STARTING INJECTORS FOR LOCOMOTIVES.

CONSIDERING the very important work the injector on a locomotive has to do, it does not appear to have received the general attention which is due to it, and the selection of a really good, economical, and reliable instrument is a matter of the first importance. As our readers are aware, the function of the injector is to feed the boiler with water; and if this cannot be accomplished, the best and most powerful locomotive is useless.

In the earlier days of the locomotive the boiler was fed by pumps, which worked when the engine was at work, and consequently the boiler could only be fed when the engine was running. This was not only a very great inconvenience, but was also very wasteful, and often in the old days the engine had to make a short trip specially to put water into the boiler. About 1859 the late Henri Giffard brought out the injector, and patented it in various countries; and one of the first Englishmen who saw the injector was the late Mr. Charles Patrick Stewart, of Messrs. Sharp, Stewart & Co., Limited, and he arranged with Giffard for an injector to be sent to his company's works in Manchester to be tested. The test proving satisfactory, Messrs. Sharp, Stewart & Co. arranged with the inventor for the manufacture of his injector in this country. The first injector was fixed on an engine running on the St. Helens branch, and the driver soon learned how to handle it, so that in two or three days he was able to feed his boiler solely by means of the injector, and to disregard his pumps altogether. The success of the injector for feeding locomotive boilers was speedily assured, and nearly all the locomotive superintendents in this country applied them to their engines.

When the injector was first introduced to the public, it was really considered a wonderful invention, and scientific men tried to explain its action, but in several instances their opinions were at variance.

For over twenty years after the first injector was put on a locomotive, very few real improvements were made, except perhaps to simplify the construction. Giffard's injector was a lifting injector, and had both water and steam regulation. Other injectors were brought out which would not lift, but which had to be fixed below the feed-water. They were very simple in design,

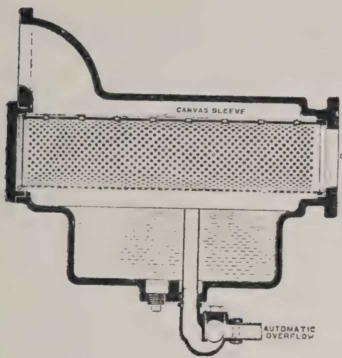


FIG. 1.—GREASE SEPARATOR.

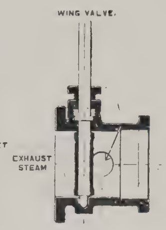


FIG. 2.—WING VALVE.

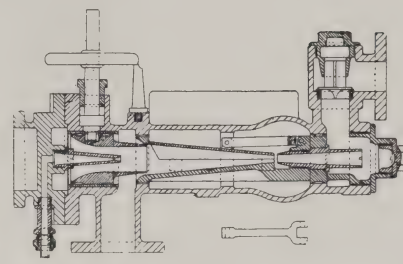


FIG. 3.—EXHAUST PORTION.

EXHAUST STEAM INJECTOR (DAVIES AND METCALFE'S PATENTS).

but only possessed a limited working range, and nothing was done to make the injector easier to handle or more reliable in its action.

Although the injector was so successful on the locomotive, yet it was far from perfect. For instance, a man required some little experience to start it, and the steam had to be turned on very gently, and often the injector would "miss," when it had to be shut off and manipulated again. Then, if the injector itself got hot by the steam blowing through, it became difficult to start, and sometimes had to be cooled; and again, if the injector broke its jet, or what is technically known as "blew-off," the valves had to be closed, and the instrument again started.

With ordinary passenger trains, stopping often, the injector was the best boiler feeder known about this time, because the drivers could feed the boiler after they shut off steam from the engine, and sufficient water would be forced into the boiler whilst the engine was standing at the station to last for the next short run. But when the days of express trains and long runs came up so prominently, it was found that the boiler must be fed at the same time that the engine was doing its work; and under these circumstances, the feeding of the boiler invariably meant a serious drop of the boiler pressure, and a consequent decrease in the power of the engine. Railway engineers were alive to the important fact, that if hot water could be put into the boiler, and especially if the water could be heated by the exhaust steam, there would be a very great economy, and engines fitted with pumps would take this hot water; but the disadvantage remained, that the engine must be "run" before the boiler could be fed. On the other hand, the injector would not take warm feed-water, and consequently, if the water in the tender got much above normal

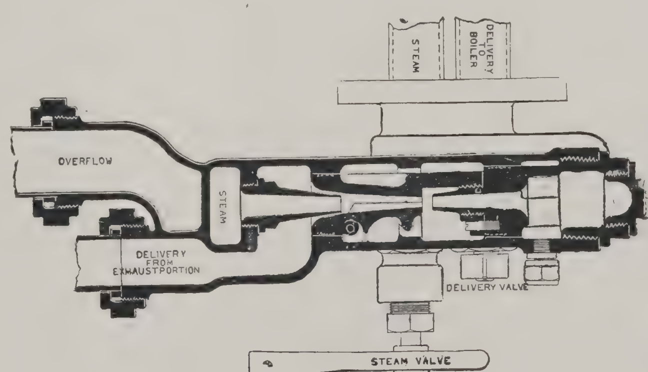


FIG. 4.—SUPPLEMENTARY PORTION OF EXHAUST INJECTOR.

temperature, the injector would not work, and this was more marked as the boiler pressures increased.

About 1880 the late Mr. Edward Davies, of Llandinam, and Mr. James Metcalfe, of Aberystwith, saw very clearly what a great advantage it would be if an injector could be made which would heat up the feed-water to a high temperature by means of the exhaust steam. There were many difficulties in the way, and the task seemed almost impossible ; in fact many engineers had tried to do this, but had signally failed. The outcome of the many experiments which were made was a combined injector, one portion being worked by exhaust steam, and the other portion by boiler steam. This injector took water from the tender at normal temperature, and by means of exhaust steam heated it to a very high temperature, and at the same time gave the water an impetus, delivering it into the second portion of the injector, which was worked by the boiler steam, and from thence it entered into the boiler. Whilst the injector was a very great advance on anything that had been accomplished before, yet it was not automatic in its action, and it was not until recently that these gentlemen so improved the injector as to make it perfectly automatic, and most suitable for modern locomotive practice.

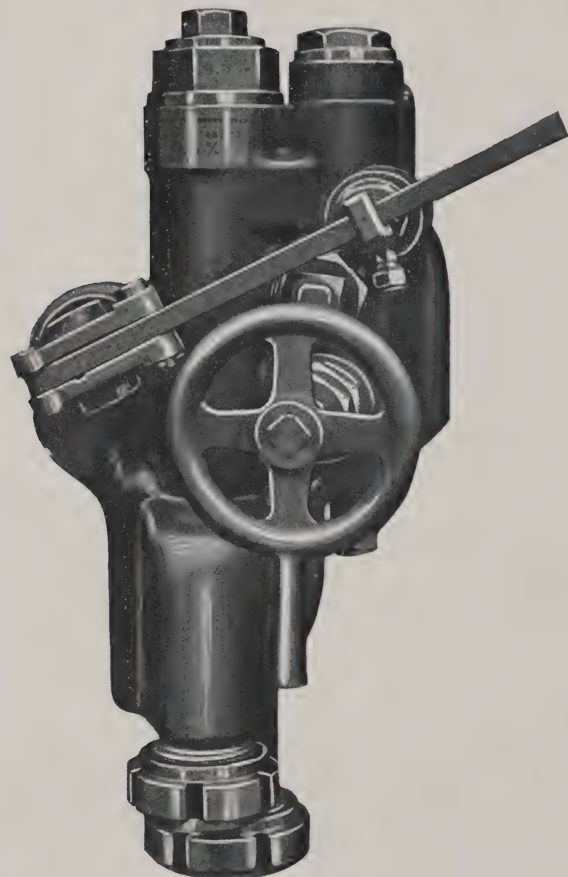


FIG. 5.—OUTSIDE VIEW OF SUPPLEMENTARY PORTION OF EXHAUST INJECTOR.

We think it will be interesting to our readers to give a few particulars of this injector, and to show what it is doing.

First, as to the manner in which it is fixed :—A branch pipe is taken from the bottom of the blast pipe, and is led to the exhaust portion of the injector, and is fixed in any convenient position below the foot-plate. The blast pipe orifice is in no way interfered with, the only alteration being about a three-inch outlet at the bottom of the pipe for the exhaust steam to get to the exhaust injector, and consequently when the injector is at work it will be clearly seen that back pressure is considerably reduced and that sparks are not emitted from the chimney so freely.

Between the exhaust injector and the blast pipe the separator is fixed, which purifies the exhaust steam from any grease or moisture which may be in it. The exhaust injector takes its water from the tender in the ordinary manner.

The live steam portion, or supplementary part, may be fixed at the back of the fire-box, and is then generally arranged in the form of what is known as a combination injector, having a self-contained clack-box and live steam valve, the delivery pipe of the exhaust portion being connected with this injector. The above will be readily identified by referring to the drawings, Fig. 1 showing the grease separator, Fig. 2 the wing valve (placed three or four feet away from injector), Fig. 3 the exhaust portion, Fig. 4 the supplementary portion, and Fig. 5 the outside view of supplementary portion. It is also shown fixed on a locomotive (Fig. 6). From information supplied to us by the makers, we can briefly say that the following is the result of its working on any locomotive carrying a pressure of 150 lb. or more. The water from the tender enters the exhaust injector at ordinary temperature (which we will assume to be 50° F.), and the exhaust steam in the exhaust injector heats this water up to 180°—190° F.; this is then delivered into the supplementary portion, and, connected by the live steam, it enters the boiler at 280° F. We thus get a positive economy in the temperature of feed-water in the exhaust injector of at least 130° F., whilst the temperature of the water entering the boiler (280° F) is so very high, and approaches so nearly the temperature of the water in the boiler itself, that there is very little contraction and expansion due to feeding by this method. In actual tests the economy in fuel has been found to be from $2\frac{1}{2}$ to 4 lb. of coal per mile run, and the economy in water about $2\frac{3}{4}$ gallons per mile run. The latter figure is for an injector of ordinary size, the larger injectors for the larger locomotives showing more.

These injectors, when applied to a locomotive, enable the boiler to be fed constantly whilst the engine is at work without any variation or dropping in the steam pressure, and it is a very great boon to have a constant feed in these days of high speed and long running. Again, when working up a bank with a heavy load, this injector can be used, and the steam pressure still well maintained.

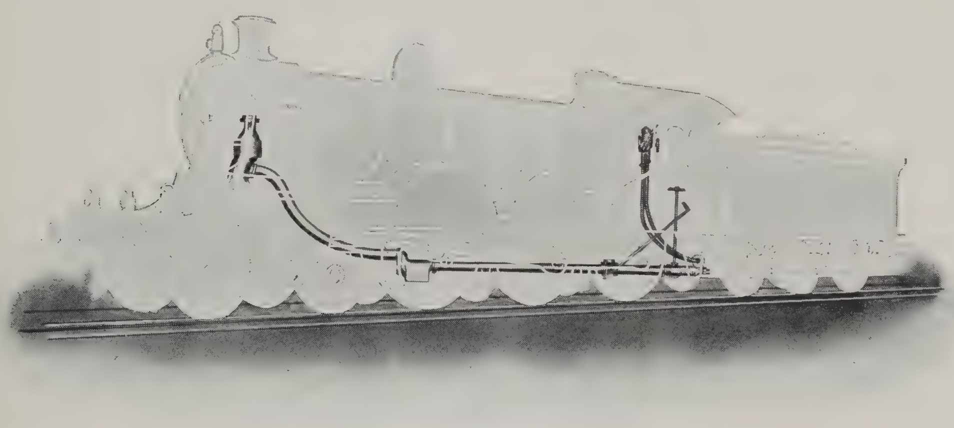
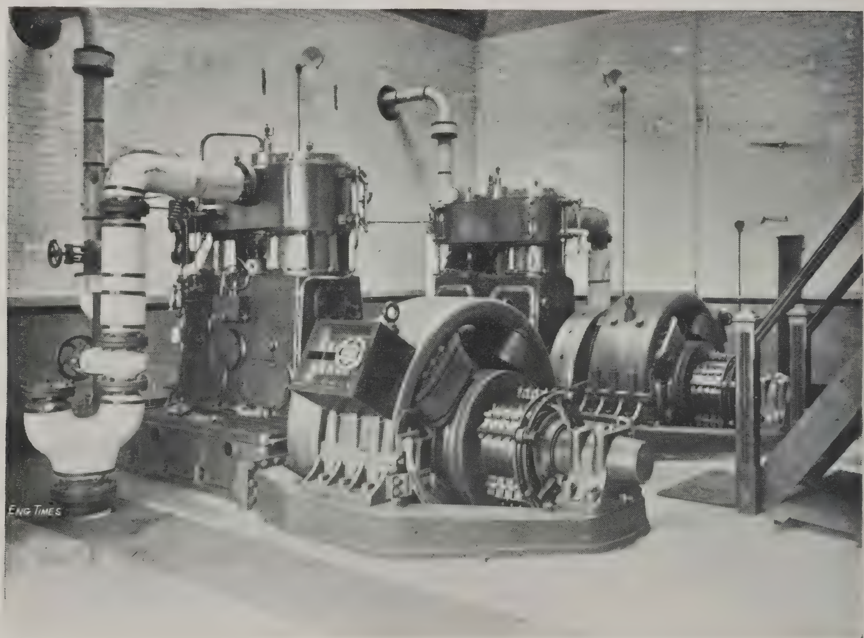


FIG. 6.—EXHAUST STEAM INJECTOR (DAVIES AND METCALFE'S PATENTS) SHOWN FIXED ON A LOCOMOTIVE

Another result of the experiments carried out in developing the exhaust injector was the introduction of the automatic, re-starting, live steam injector, and Messrs. Davies and Metcalfe were not only the pioneers of injectors worked with exhaust steam, but were also the first to bring out the re-starting or self-acting

live steam injectors, and the live steam injector now made under their patents differs from the Giffard injector mentioned above in the fact that it needs no delicate handling to start it. Either *steam* or water may be turned on first, and the injector will work. Should the injector cease working through vibration or shock, it will itself instantly re-start. These injectors, both exhaust and live steam re-starting, are now adopted by the leading railway companies. The makers are the Patent Exhaust Steam Injector Co., Limited, of 4, St. Ann's Square, Manchester, and Injector Works, Romiley, who we may say are successors to the injector business of Messrs. Sharp, Stewart & Co.



HIGH-SPEED STEAM-DYNAMOS AT THE BIRKENHEAD TRAMWAYS POWER STATION, BUILT BY MESSRS. ERNEST SCOTT AND MOUNTAIN, NEWCASTLE-ON-TYNE

POWER STATION ELECTRIC GENERATING SETS.

WE give an illustration representing two of Messrs. Ernest Scott and Mountain's enclosed high-speed steam-dynamos, which they recently have supplied in connection with the electric tramways for Birkenhead. These have been installed at the sub-station which the Corporation have recently erected in New Chester Road, adjoining the Destructor buildings, and are to supply the current for the southern portion of the borough.

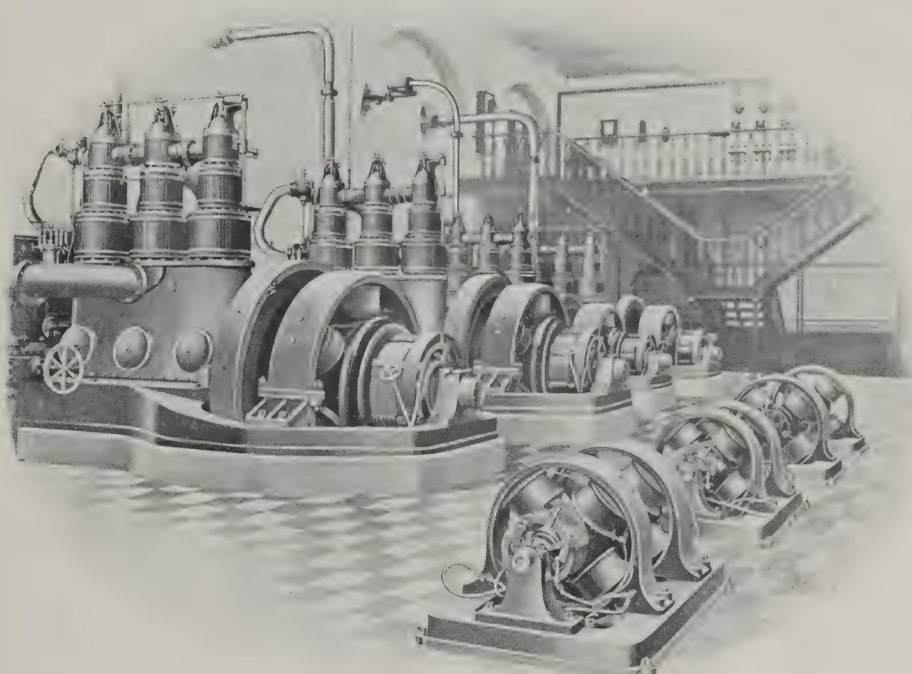
The plant consists of two of Messrs. Scott and Mountain's enclosed compound, central valve, self-lubricating, high-speed steam-engines, each of 240 i.h.-p., and each having cylinders of the following dimensions:—

Diameter of h.-p. cylinder ..	$11\frac{1}{4}$ in.
Diameter of l.-p. cylinder...	20 ,,
Stroke	10 ,,
Revolutions	360

Steam pressure, 140 lb., condensing with a vacuum of 24 in.

The engines are each fitted with a governor of the throttling type, fitted with bye-pass enabling the steam to enter the low-pressure cylinder direct in the event of a sudden overload being

thrown on the engine. There are also fitted a steam separator with connecting pipes, cocks, as well as indicator gear and the usual accessories. The engine is erected upon a combination bed-plate of cast-iron, which is arranged to take the generators, which latter are also of Messrs. Scott and Mountain's make of the four-pole type, with slotted drum armatures, each giving an output of just completed four similar sets for the Darlington Corporation, equal to 400 h.-p., three sets for Worksop Corporation, three sets for Worthing Corporation, and three sets for the Hill of Howth Electric Railway in Ireland. We hope later on to give notices of these plants, which we have no doubt will be of interest to all our readers.



WIGAN CORPORATION POWER HOUSE.

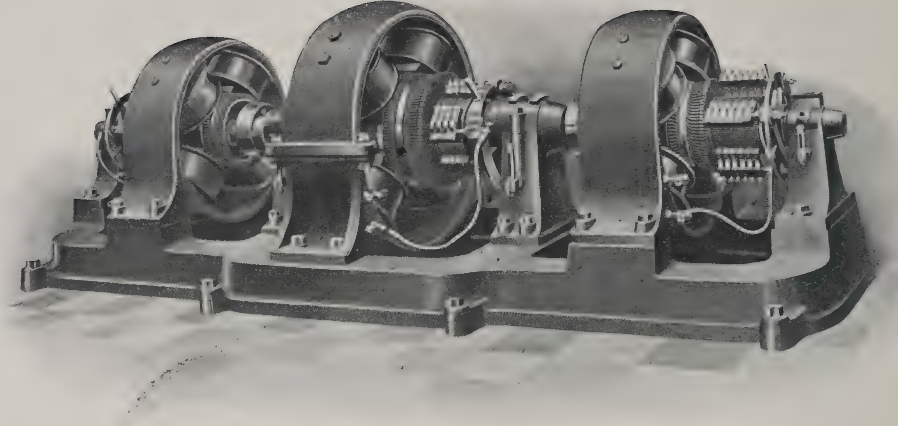
273 amperes at 550 volts. These dynamos, when running as shunt machines with all adjusting resistance of the magnets cut out, will be capable of giving an E.M.F. of 600 volts at the normal speed. Each is complete with two two-shunt breaking switches and resistances, two regulating switches and resistances, and two diverting series switches for adjusting the strength of the compounding coils on the machines. Messrs. Scott and Mountain have also

GENERAL ELECTRIC CO.'S

TRACTION AND LIGHTING SETS.

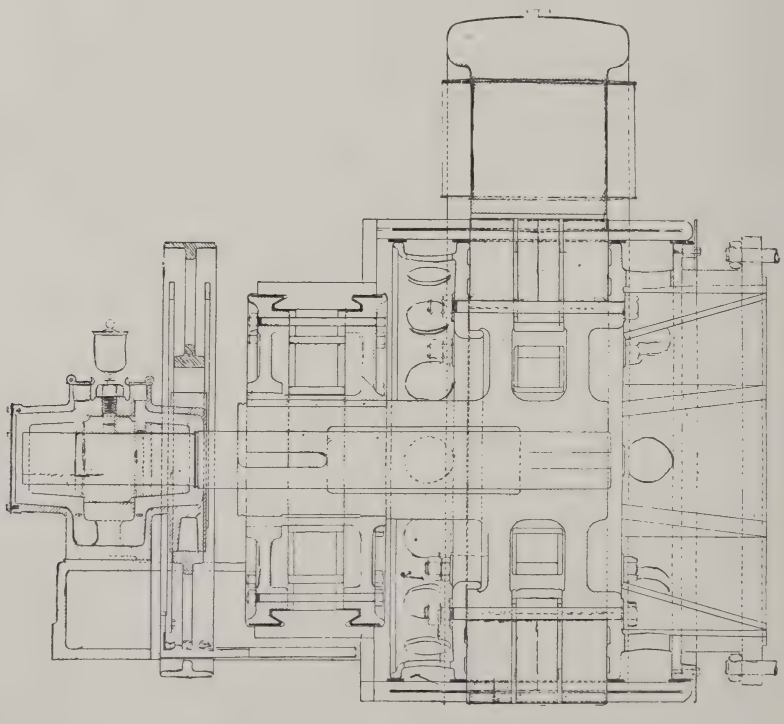
THERE have been recently installed for the Wigan Corporation an interesting series of traction and lighting generators direct coupled to Willans' engines, together with auxiliary machines, consisting of balancers, boosters, motor-generators, etc., by the General Electric Co. (1900), Limited, Peel Works, Adelphi, Salford.

The generators are of two sizes, viz.,



STANDARD BOOSTER SET, BY THE GENERAL ELECTRIC CO.

two of 210 k.w., and two of 160 k.w. capacity. They are of the 6-pole type, and have very light field construction, the larger sizes especially so. The armatures are of large diameter, the core diameter being about 3¾ times its length. The cores are slotted, having six conductors per slot, with 160 slots. The General Electric Company claim, by suitable design of the proportion of the slots and frequency of commutation in these machines, that they can get sparkless running with fixed position of brushes from no load to 30 per cent.



PART SECTION OF "BYNG-HAWKINS" DYNAMO.

overload on traction work, without the aid of any auxiliary windings, etc.

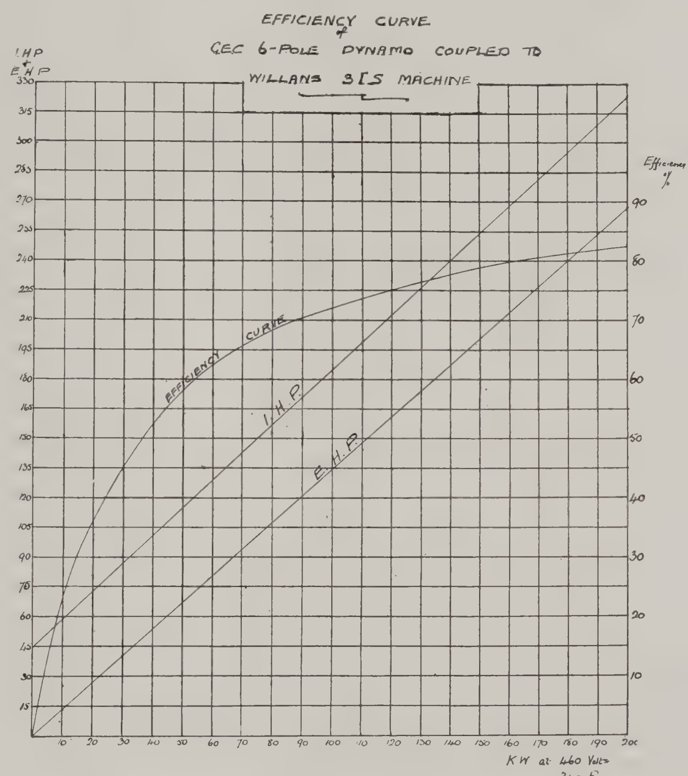
It is interesting to note, that in the larger sizes the armatures of the machines are practically as powerful as the field magnets, and yet in the case of the machines at Wigan, and also two absolutely duplicate machines recently supplied to the Ilford Urban District Council, the brushes remain from 4 to 5 sections in front of the neutral line, from no load up to 30 per cent. overload, as before mentioned.

The compounding can, of course, be cut out by means of the switch provided, when the machines are to be run on lighting. From the part section given, it will be seen that the armature is well ventilated. This is proved by the temperature of the machines taken after six hours run at full load, and a seventh hour at 25 per cent. overload, the highest temperature being on the armature core, which rose 45° Fahr. above the atmosphere.

From the efficiency curve given, it will be seen that the combined efficiency of the 210 k.w. sizes is 82·96 per cent., this being taken during the first run at the engine makers' works.

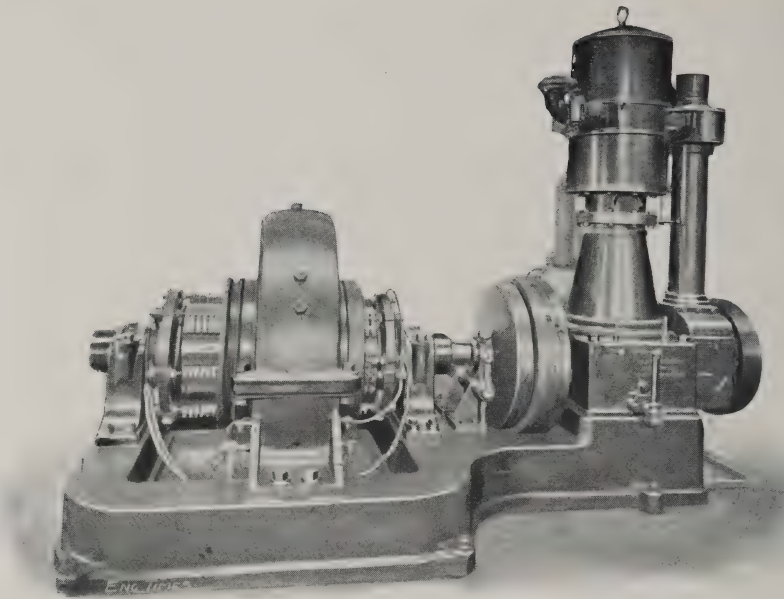
The machines having given general satisfaction, the General Electric Company have recently received a repeat order for two 210 k.w. machines direct coupled to Willans' engines.

The auxiliary machines consist of 7 balancing transformers to compensate for 100 amperes out of balance in the middle wire on lighting. These machines are of the single-field, 4-pole type, of a specially neat and light construction. Also 3 track boosters, having an output of 500 amperes at 20 volts. These boosters are motor driven, and are also of the 4-pole type. They are provided



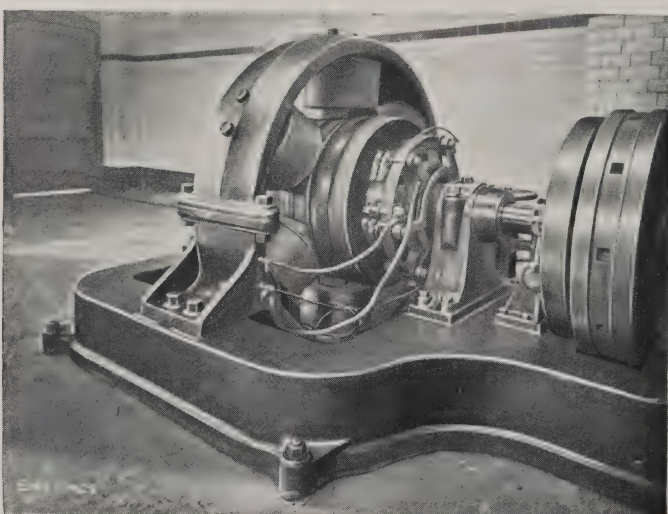
with a special switch of the Company's design for cutting them out of circuit whilst running. Two motor generators, having an output of 100 amperes, 100 volts, are provided for cell boosting.

The above Company have also supplied many boosters and balancers, similar to the one shown in the illustration, for the British Electric Traction Company's power stations at Kidderminster, Merthyr, Stoke, etc., the last-mentioned being a single-field machine with a third brush arrangement on the



STOKE TRAMWAYS MOTOR-GENERATOR.

500 volt commutator, by means of which the machine can be started up as a series machine from the third brush; and when full speed is attained, the field, which is excited at 110 volts, can be thrown over on to the low tension side.



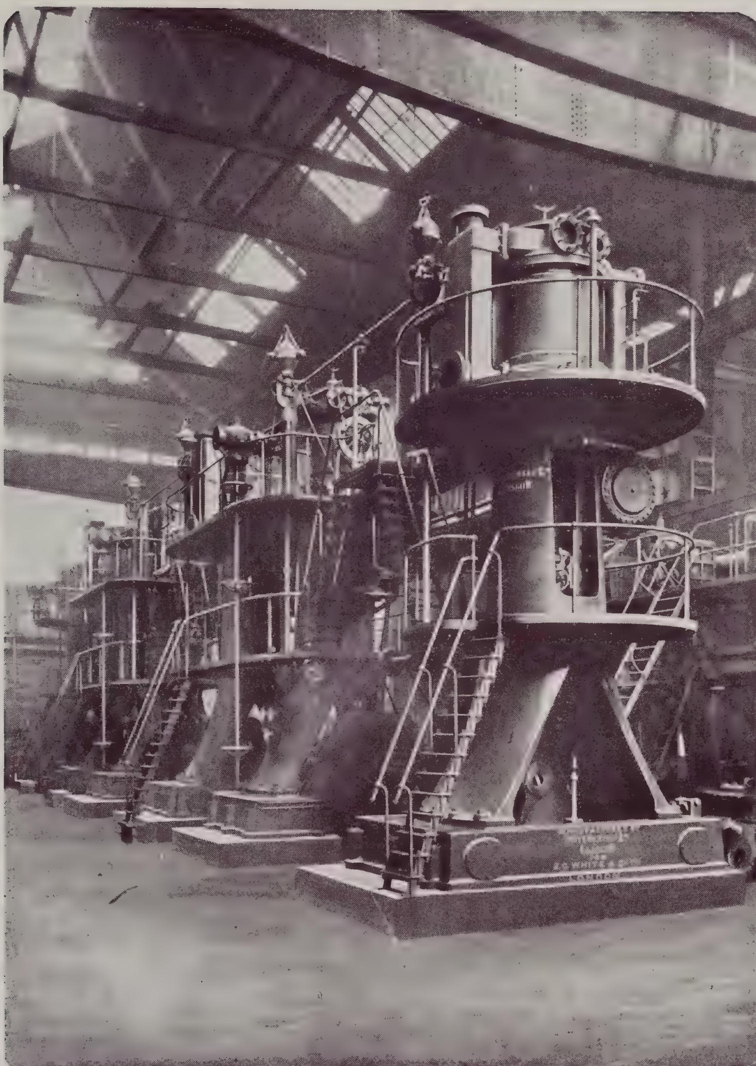
ANOTHER VIEW OF THE STOKE TRAMWAYS MOTOR-GENERATOR.

MATHER AND PLATT'S

GENERATING SETS FOR TRACTION WORK.

A GOOD example of the modern type of combined engine and dynamo for electric-power station work is afforded in the case of the Blackpool and Fleetwood Tramway. The engine house at the present time contains five sets of generating plant, and a general view of these sets, as well as of the switchboard and three boosters, is given in the illustrations, Figs. 2 and 3. The makers are Messrs. Mather and Platt, of Manchester.

The engines are of the open vertical marine type (Figs. 2 and 3), mounted on



THREE VERTICAL CROSS-COMPOUND 800 H.-P. "CORLISS" ENGINES.

Being installed by J. G. White & Co., Limited, London, for the Kalgoorlie Electric Power and Lighting Corporation, Limited, for their power station at Kalgoorlie, Western Australia. Manufactured by D. Stewart & Co., Limited, of Glasgow.

cast-iron bed-plates of box section. At the back are cast-iron standards for carrying the cylinders, which are further supported in front by polished steel columns. The engines are double-acting compound condensing, the cylinders being respectively 12 in. and 24 in. in diameter, while the stroke is 16 in.; the speed is 165 revolutions per minute, and at this speed, with a steam pressure of 120 lb. per square inch, the engines will each indicate 200 h.-p. The pistons are provided with Mather and Platt rings packed with metallic packing; the cross-heads move in special guides bolted to the cast-iron standards; the double-webbed cranks are forged solid with the shaft at 180 degrees from each other. The steam distribution is effected by double slide-valves, and controlled by a Pickering throttle governor, while hand regulation is provided for the expansion gear.

The dynamos are of Mather and Platt's usual six-pole type, mounted on an extension of the engine bed-plate. The yoke ring and magnet poles are cast in one of steel of high magnetic permeability; the ring is in two parts, so that the upper half can be readily lifted off; the magnets are shunt wound. The armatures are of the drum type, the specially insulated conductors being completely embedded in the slotted core. The dynamos are built for an output of 120 kilowatts at 505 volts, and have an efficiency of 93 per cent.; they run very cool, the rise in temperature when working continuously on full load not exceeding 25° C. in any part of the machine.

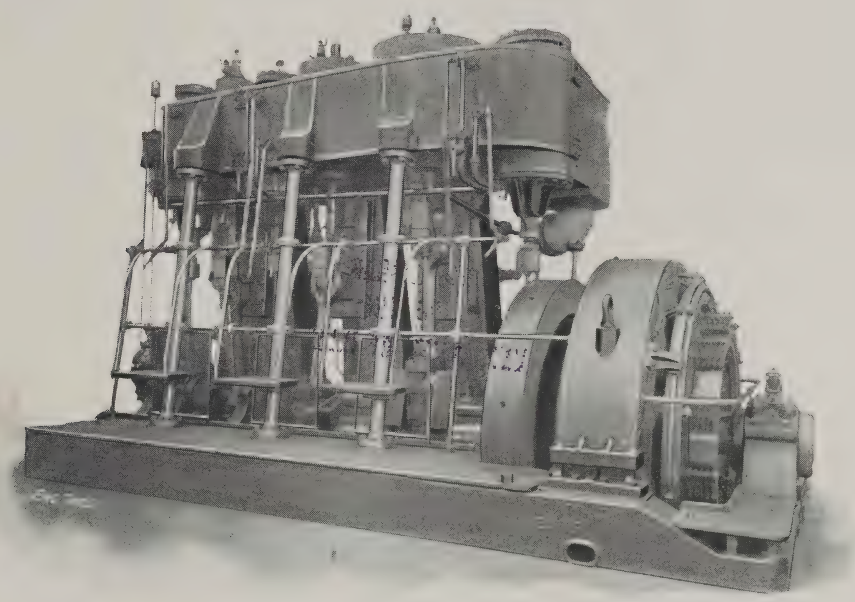
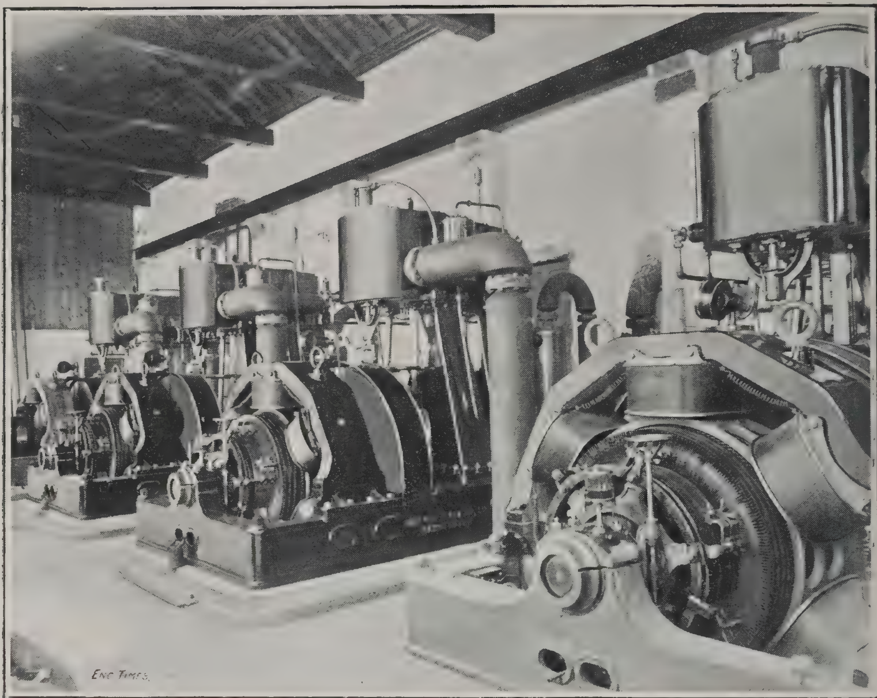
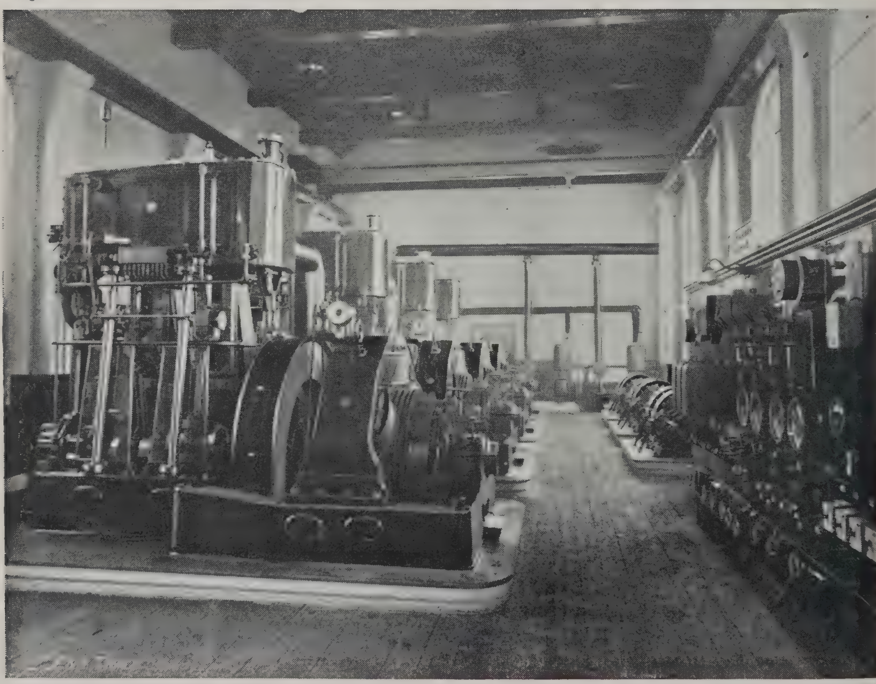


FIG. 1.—AN 800 H.-P. ELECTRIC GENERATING SET, BY MESSRS. MATHER AND PLATT, MANCHESTER

The boosters are four-pole motor-generators, mechanically coupled and mounted on a common bed-plate, the construction of both the motor and generator side being similar to the generators already described above. The motor side is connected to the bus bars through suitable switches, while the generator side can be connected to any feeder.

The further illustration (Fig. 1) is of a similar set of engine and dynamo, but





FIGS. 2 AND 3.—VIEWS IN THE BLACKPOOL AND FLEETWOOD TRAMWAY POWER STATION.

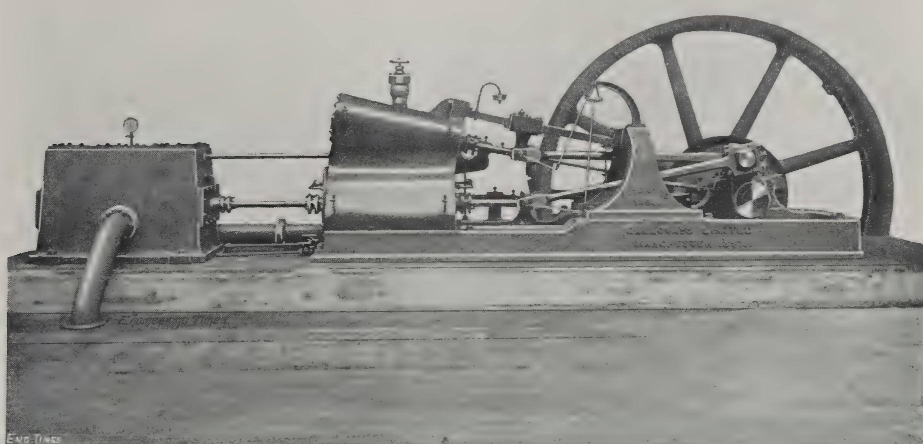
of larger size, to which the above description would apply with the following alterations. The engine is triple expansion, the cylinders being respectively $17\frac{1}{2}$ in., $28\frac{3}{8}$ in., and $45\frac{1}{2}$ in. in diameter, with a stroke of 21 in., and running at 110 revolutions per minute. At this speed, and with a pressure of 200 lb. of steam, the engine will easily indicate 800 h.-p. The steam distribution in this case is effected by means of piston valves to all three cylinders, the regulation being effected by means of a governor acting directly on the throttle-valve. The dynamos have twelve poles in this case, and are constructed for a normal output of 400 kilowatts, though they not infrequently give a maximum of 500 kilowatts.

It will be of interest to note that these larger sets run for periods of from sixteen to eighteen weeks, day and night, without a single stop.

• • •

A SUPERPOSED COMPOUND ENGINE.

WE illustrate one of two 375 h.-p. engines built and supplied by Galloways, Limited, for the City of Birmingham Cable Tramways Co., Limited, to drive the cables operating the cars in use in that city. It is of the makers' superposed compound type, having the high-pressure cylinder fixed above the low-pressure. These are respectively 20 in. and 36 in. diameter, both arranged for a stroke of 4 ft. For the purpose of this installation, the speed is 55 revolutions per minute, and the boiler pressure being 75 lb., the indicated h.-p. under these conditions developed by each engine is 375. The high-pressure cylinder is fitted with piston valves, the governor being of the shaft type, keyed on to crank shaft, and arranged to automatically vary the throw of the excentric actuating the high-pressure valves. The cylinders are provided with metallic pistons, and the piston and connecting rods are of steel, of ample proportions. The crank shaft is of mild steel, with cast-steel crank and crank pin. Each fly-wheel has a weight of 20 tons. The condenser is fixed in rear of engine, the air-pump being horizontal, double-acting, and worked direct from piston-rod of low-pressure cylinder.



375 H.-P. SUPERPOSED COMPOUND ENGINE.

The special feature of this engine is

its superposed arrangement, and it becomes particularly adaptable where space is limited. Another advantage is that the distance traversed by the steam between the high and low pressure cylinders is considerably reduced. The makers state these engines are capable of developing upwards of 500 indicated h.-p. at an increased speed, and with an improved boiler pressure.

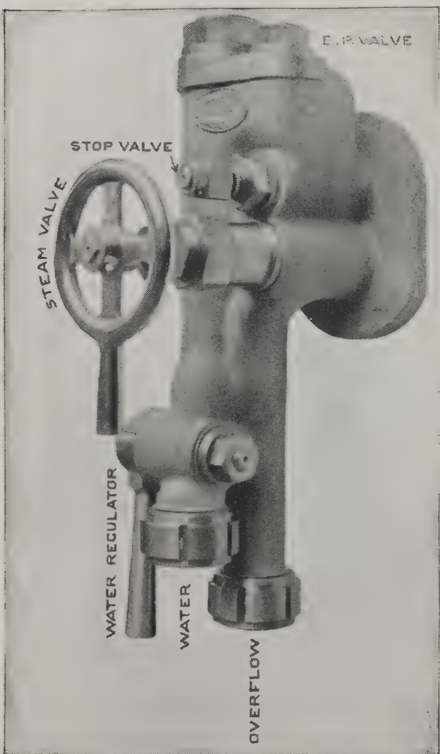


FIG. 1.—GRESHAM AND CRAVEN'S VERTICAL COMBINATION INJECTOR.

MODERN LOCOMOTIVE BOILER FITTINGS.

It is now the practice, in England, on the Continent, and to a lesser degree in America, to group all the appliances for working the boiler, engine and train in the cab of the locomotive, right under the hand of the driver and his fireman, on the former of whom has now fallen the onerous duty of keeping the compartments of the train at a suitable temperature, since the general introduction of steam-heated trains. For many years the back of the boiler was only ornamented with the regulator, the water gauge glass, and possibly three try cocks. The first addition to be bolted to the boiler back was the combination ejector for working the automatic vacuum brake, which was designed by Mr. Gresham, of Gresham and Craven, of Manchester, who are the makers of that brake, the object being to reduce the number of parts and facilitate the fixing by suppressing long rods and pipes, the exhaust from the ejector passing through an internal pipe in the boiler to the smoke-box.

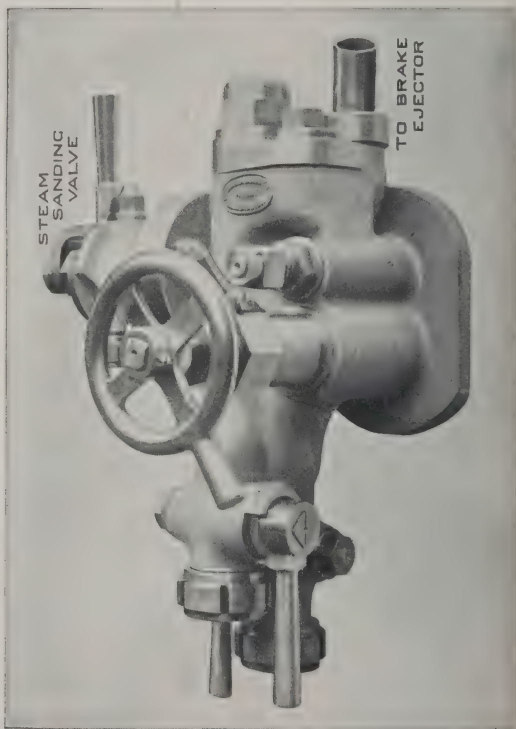


FIG. 2.—INJECTOR COMBINED WITH STEAM SANDING VALVE.

The same firm soon after introduced the combination injector, of which we give three illustrations.

Fig. 1 represents the usual type of

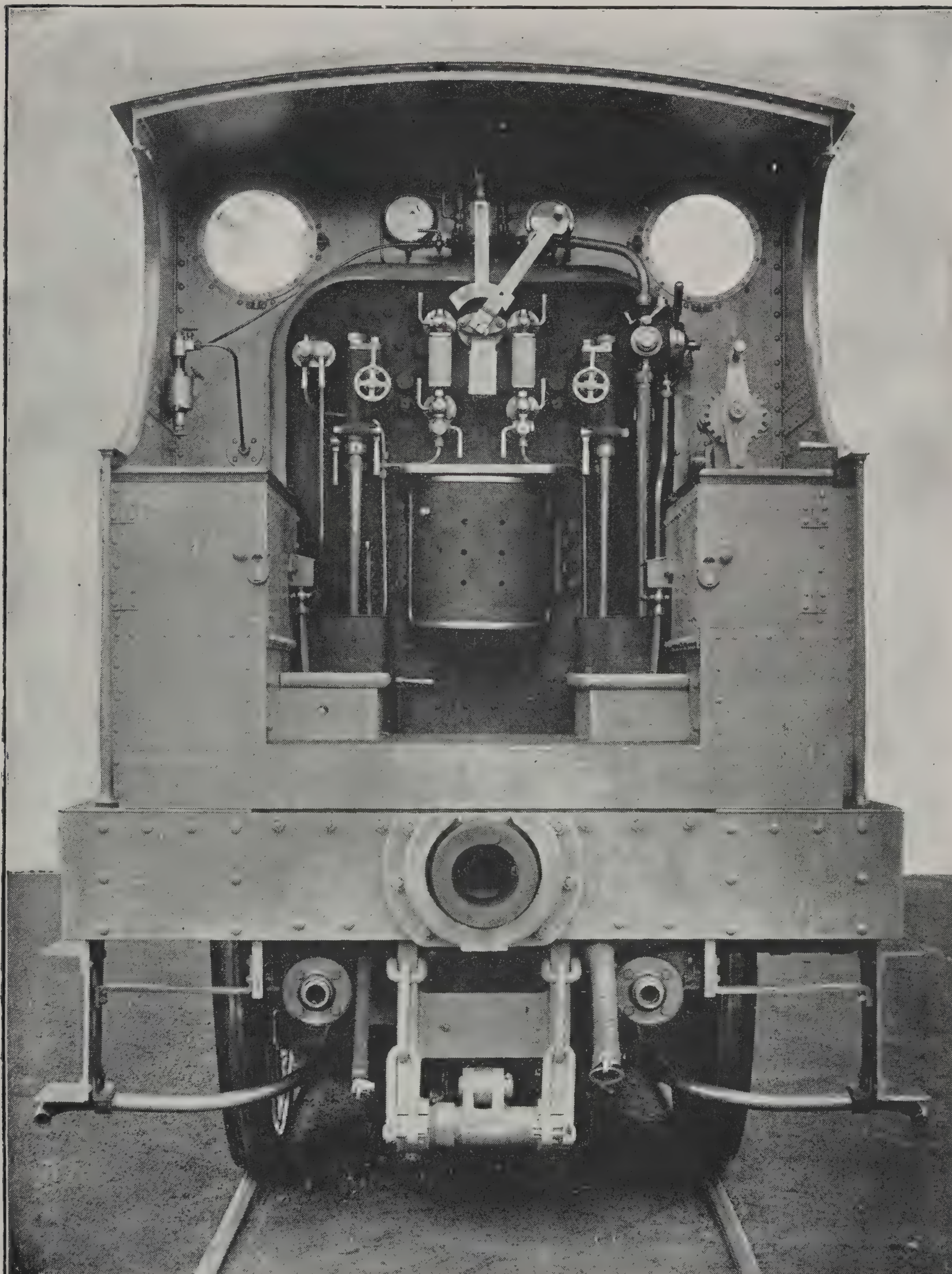


FIG. 3.—VIEW SHOWING THE FITTINGS ON THE FIRE-BOX OF A MODERN LOCOMOTIVE.

vertical combination injector which has all the necessary valves, self-contained, and bolts on to the back of the boiler with one flange, the steam and delivery being conveyed by internal pipes, which cannot burst, as they are not under pressure, nor can they freeze.

Fig. 2 shows how the injector can be combined with other fittings. The one in question carries a steam sanding valve for Gresham's patent sanding apparatus, and has a separate steam branch for supplying steam for any other purpose; thus one connection with the boiler serves for three in the ordinary course, and we think every one will admit the fewer holes drilled in a boiler the better. The large illustration (Fig. 3) clearly shows what a modern locomotive footplate is like; the Belpaire firebox might have been designed to accommodate so many appliances — combination ejectors, combination injectors, combined sanding and blower valve, combined train-heating valve and relief valve.

SINGLE-DRIVER EXPRESS PASSENGER LOCOMOTIVE, GREAT NORTHERN RAILWAY (MR IVATT).

NEW MACHINERY, APPLIANCES, ETC.

(*Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated so far as possible by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.*)

KINNEAR STEEL ROLLING DOORS.

THE present state of the transport world is essentially one of progress. Increased speeds, improved accommodation, more efficient service, and better and more economical methods are subjects engaging the constant attention of the engineer; and nothing that will contribute towards these ends escapes his consideration. What was thought good enough yesterday is antiquated to-day; and the manufacturer who would not be left hopelessly behind must satisfactorily meet the new conditions. As a consequence, much time and thought has been expended in perfecting details which are of minor importance in themselves, but whose perfection or imperfection materially affect the high standard of results aimed at by the engineer.

An illustration of this is furnished by the doors used for tram-car sheds, round houses, goods stations, etc. Formerly, cumbrous wooden doors, made to swing or (more often than not) to slide, were employed. Much force and time were needed to move them, and if exposed to a high wind they became almost unmanageable. Repairs were costly, and an additional drawback in the case of trolley roads was caused by the awkward break between the trolley wire inside and outside the car shed. To meet these difficulties an attempt was made to use the ordinary rolling shutters, sometimes made of wood, sometimes of iron, as used for shop fronts. These, however, were not adapted for such large openings. If made stiff enough the weight was prohibitory, repairs were too difficult and costly, and where used for tram-car sheds the break in the trolley wire still remained.

The Kinnear Manufacturing Co., of Columbus, Ohio (represented in this country by The B. & S. Folding Gate Co., of 19, 20 and 21, Tower Street, Upper St. Martin's Lane, W.C.), have now surmounted the difficulties, and are making a steel rolling door which meets all the requirements. It is light, yet of great strength; easily and quickly worked; repaired (if injured) with a minimum of time and expense; and where used for tram-car sheds, the break in the trolley wire is satisfactorily bridged. Single doors have been made for openings up to 35 ft. 6 in. wide, and up to 28 ft. high.

The accompanying diagram (Fig. 3) shows the slats composing the door in cross section. Slat No. 1 is used for all ordinary doors up to 10 ft. in width; for openings over 10 ft. in width greater stiffness is required, and in such cases slat No. 2 is used. Slat No. 3 is used for small openings, such as windows. As a rule, No. 22 gauge steel is used, but a lighter or heavier gauge can be employed where desirable. It will be noticed that the slats form their own hinge, which extends their entire length. By removing the detachable side groove, any damaged slats can be instantly slid out and replaced by new ones.

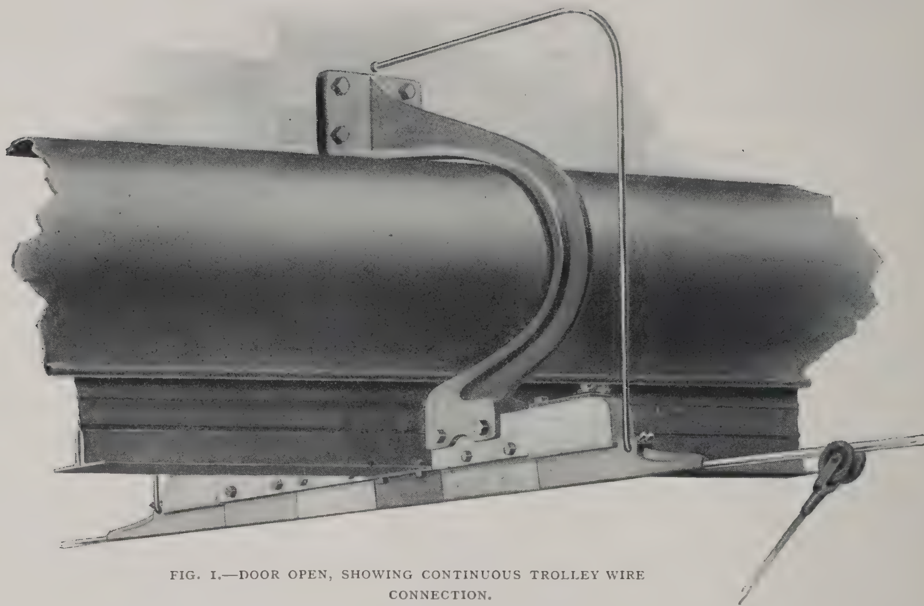


FIG. 1.—DOOR OPEN, SHOWING CONTINUOUS TROLLEY WIRE CONNECTION.

These doors are worked by a hand chain and gearing. The barrel on which the door coils contains a spring which counterbalances the weight of the door, enabling it to be opened or closed with the greatest ease and rapidity. In some cases this spring is made of such strength that when the door is raised

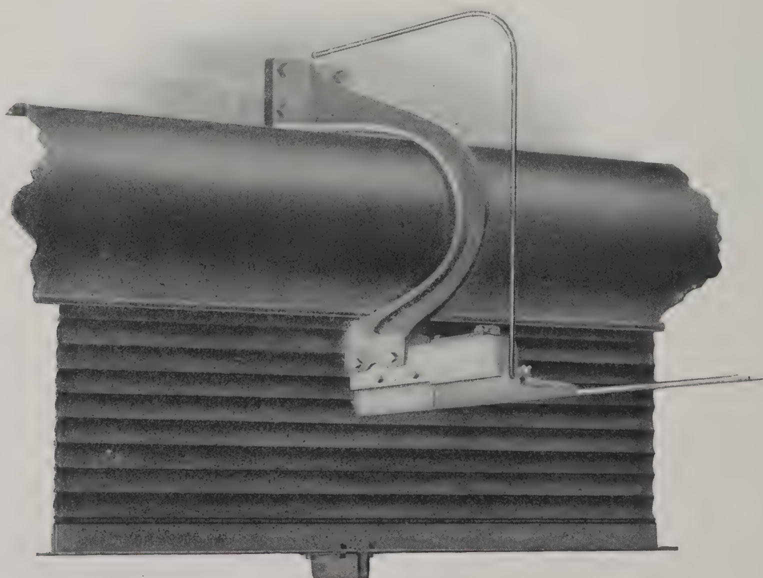


FIG. 2.—DOOR PARTLY CLOSED, SHOWING BREAK IN TROLLEY WIRE.

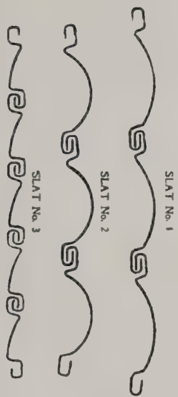


FIG. 3.—DIAGRAM OF SLATS COMPOSING DOOR.

six or eight feet, it will open the balance of the distance automatically. This prevents an employee leaving the door only partly open, and thus avoids accidents. The illustration (Fig. 4) of a car shed shows an opening having five doors. If desired, the intermediate posts can be made hinged; then, after the doors are open, the posts can be quickly and easily swung to the ceiling, giving an entirely clear opening.

The trolley wire connection provided for use in conjunction with these doors is well shown in the accompanying illustrations (Figs. 1 and 2). One being maintained by means of the wire passing through the wall above the door, and connecting the trolley wire outside and inside the car shed.

These doors provide an excellent means for increasing the accommodation of round houses. Modern requirements have called into existence a larger type of locomotive, which in some cases is too long for the old round house. The accompanying plan illustrates the method adopted to meet the new conditions, providing the extra room required without disturbing the existing building or making any change in the pits or ventilators. Referring to the plan, it will be noted that the locomotive extends some distance beyond the line of the old wall of the round house. To meet this difficulty, wrought iron columns are provided to form the necessary grooves for the doors to operate in; these columns are

FIG. 4.—CAR SHED FITTED WITH KINNEAR DOORS.

shows the door when up, providing automatically for an uninterrupted trolley service. The other shows the door partly down, and it will be noticed that the operation of the door does not in the least interfere with the current in the trolley wire, the electrical circuit placed at the requisite distance from the old wall, and the original roof line is then extended to cover them, while between the columns are placed the rolling doors. Where the clearance in height is sufficient, glass transoms can be placed above the doors, providing

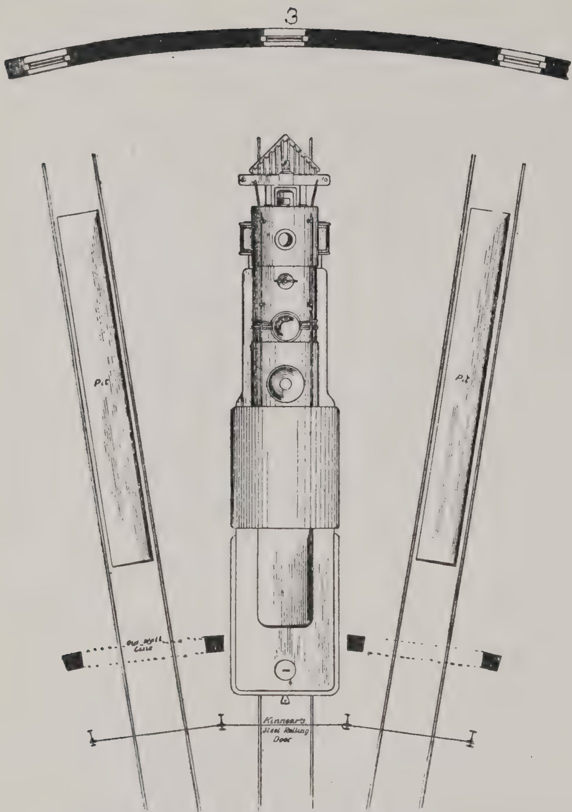


FIG. 5.—METHOD OF INCREASING SIZE OF OLD ROUND HOUSE BY USE OF KINNEAR DOORS

ample light. One of the round houses of the Hocking Valley Railway Company, treated in the way described, is shown in connection with this article. The facility afforded for meeting present and future requirements quickly and economically is obvious.

An important consideration in most cases is the protection against fire which is afforded by these doors. Owing to their ingenious construction the various parts, even to the individual slats, can expand or contract independently. This effectually prevents any buckling, and keeps the door intact even under the severest tests. If a fire breaks out inside the building, it can be completely confined. If the various departments are separated by these doors, then the fire can be confined to the department in which it breaks out. If the fire is in a neighbouring building,

FIG. 6.—ROUND HOUSE FITTED WITH KINNEAR DOORS.

these doors prevent its entrance into the bnilding fitted with them. Of course, where this security is desired, the windows must be fitted with shutters made on this principle. Where desired only as a fire protection, they are sometimes made to be normally held open by a fusible link, graduated to fuse at one hundred and fifty degrees of heat. Springs under tension are in such cases attached to the bottom of the shutter at each side, and these give it an impulse, causing it to descend rapidly when released by the melting of the fusible link.

It may occur to the reader that in the case of a building equipped with these automatic fire shutters, a fire inside might cause the shutters on an upper floor to close, preventing the firemen from playing a stream of water into the burning room until the arrival of ladders enabled them to open the shutters; but even this contingency has been provided for. Each shutter can be fitted with a small water wheel, so ingeniously arranged that when the firemen direct a stream of water from a fire-hose against the wheel, it instantly revolves and coils up the shutter. This construction works admirably for any height that can be reached by a stream of water from a fire-hose.

The doors and shutters are made for all sorts of openings, and to meet any requirements, and undoubtedly mark a very decided advance in this line.

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"HELIOS" AUTOMATIC CUT-OUT.

A MOST important point in the transmission of power by continuous current electrical machines, and more especially in the case of electric traction, is the protection of the generators, motors, and conductors against damage by excess of current due to overload or short-circuit.

Automatic cut-outs are now generally employed for this purpose in place of safety-fuses, and there are several designs of such cut-outs on the market, the majority of which are actuated by a spring set free by the armature of an electromagnet. The arrangement is generally such that a hand switch has to be placed in series with the cut-out, as, in order to close the circuit again after interruption by the automatic cut-out, the hand-switch must first be opened, the cut-out reset, and then the hand-switch closed again. Should the short-circuit still exist, however, the rush of current not only sets off the cut-out again with excessive sparking at the contacts (which are thereby gradually destroyed), but also causes considerable damage through sparking at the commutators of the dynamos. As a result of such sparking at the contacts, the cut-out soon refuses to act when a short-circuit occurs, and extensive injury is done to the generators and conductors in consequence.

We give illustrations of the new "Helios" automatic cut-out supplied by Messrs. Frank Suter & Co., Limited, of 66, Berners Street, London, who claim that this apparatus not only overcomes the defects and drawbacks which we have just referred to, but also possesses the following advantages:—

1. The automatic cut-out and hand-switch are combined in one apparatus.

2. Permanent closing of the circuit is prevented as long as the short-circuit exists.

3. Violent sparking at the contacts is avoided at "make" and "break" by the insertion of a resistance at the first and last moment of contact.

4. The construction is such that the arc at "break" cannot destroy the contacts, nor bridge across to any other conducting part of the mechanism.

The manner in which the apparatus (shown in Figs. 3 and 4) works is, shortly, as follows:—

On closing the switch, immediately

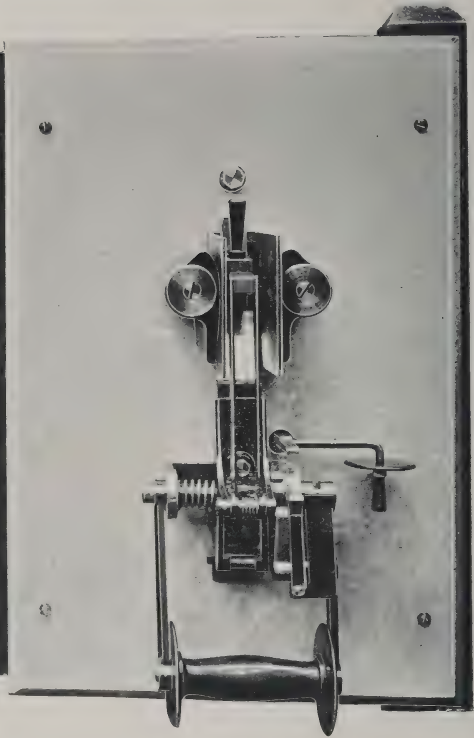
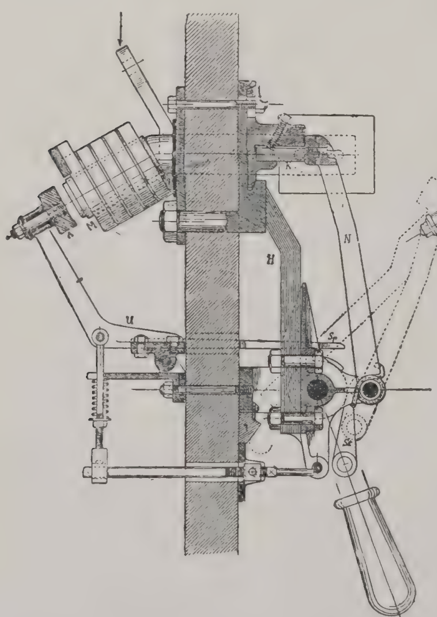


FIG. 1.—VIEW FROM REAR OF SWITCH-BOARD. FIG. 2.—VIEW FROM FRONT OF SWITCH-BOARD (SWITCH OPEN).

"HELIOS' AUTOMATIC CUT-OUT



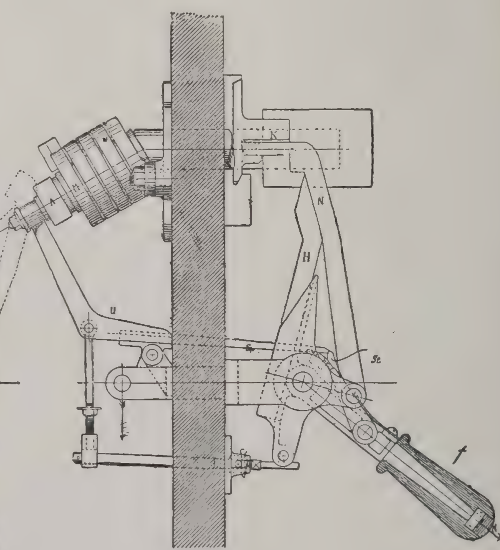


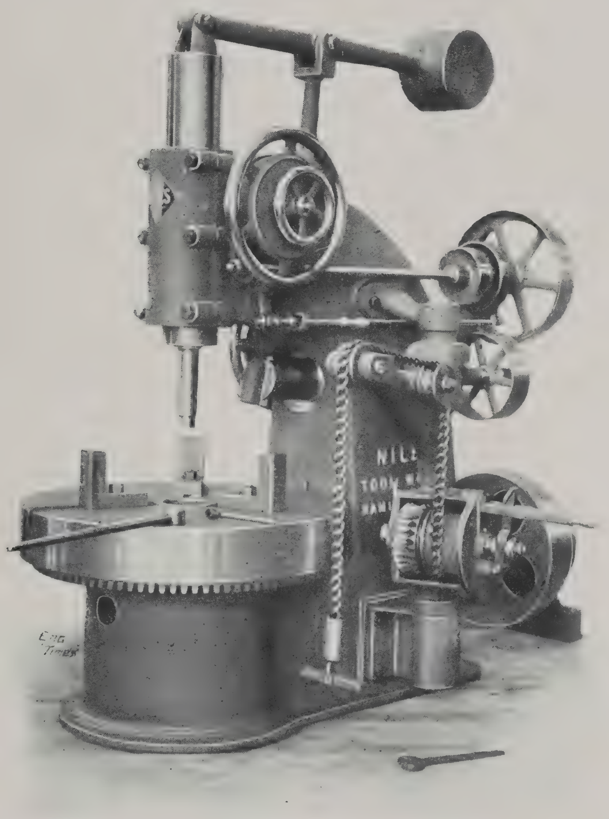
FIG. 3.—LONGITUDINAL SECTION (SWITCH CLOSED). FIG. 4.—SIDE ELEVATION.

"HELIOS' AUTOMATIC CUT-OUT.

the lever N touches the contact K (which is of high resistance) the electromagnet M—in the event of excess current or a short circuit—attracts the armature A, and through the agency of the bent lever U depresses the pawl Sp. By means of the stop-catch St the switch-arm is disengaged from the handle and snaps back into its initial position, it being impossible to hold the switch "on" as long as the short-circuit exists. The contact K must be a high-resistance carbon contact, as it is necessary to provide for the interruption of the circuit when the current is only slightly above normal. Thus the sparking which may occur can only be approximately such as that which takes place with the usual maximum current strength.

A special feature of the automatic cut-out is the employment of the electromagnet to form a magnetic "blow-out" at the point of separation of the contacts.

This apparatus is made in two forms, the one adapted for switch-boards and the other for tramcars.



CAR-WHEEL BORING MACHINE.

The automatic cut-out, with locking device, for tramcars may be fixed to the roof of the platform above the driver, or in the covering now frequently provided for the platform. This form of cut-out serves as a substitute for the safety-fuse, which has proved far from reliable; it thoroughly protects the motor against overloading, and prevents the driver closing the switch too rapidly. Since the driver is compelled to drive more

carefully, the rolling stock is saved, and the reaction of the varying load at the central station diminished. These cut-outs may be employed for continuous-current circuits up to 600 volts pressure, and are adapted for all the various systems of transmitting power, for the protection of the generators and motors.

• • •

CAR-WHEEL BORING MACHINE.

WE illustrate a machine designed especially for small car-wheel, gear and other miscellaneous boring, large quantities of which it is capable of turning out. Its simplicity, ease of manipulation, convenience of clutch and operating levers, combining solidity and efficiency, are the essential features of this machine. The table is 41 in. diameter, and contains a self-centering chuck operated by a single motion of a cam lever. The chuck slides have small movement for gripping only. They are slotted and corrugated on top to fit corresponding corrugations on the jaws, and are also graduated in inches. This effectually prevents the slippage of the jaws. The jaws may be set at any point on the slides. This makes an excellent quick-working chuck for all diameters of wheels. The table is driven by cut bevel gearing from a cone in the rear. The boring spindle has power down feeds and quick hand movements. Two fine feeds are provided for roughing out and one coarse feed for finishing cuts. A very efficient and quick acting power crane is mounted on the side of column for handling wheels. A power hub-facing bar passes through the column at the proper height for the hub. It carries an adjustable tool slide at the end, and has power feeds and hand movements. It is operated from the rear side on account of the crane. This eminently useful tool is made by the Niles Tool Works Co., of 23 and 25, Victoria Street, London, S.W.

THE VICARINO ELECTRIC SYSTEM OF RAILWAY CARRIAGE LIGHTING.

THE idea is by no means a new one to employ for lighting each carriage a dynamo and accumulators, the latter supplying current to the lamp circuit when the train is at rest, and the dynamo sometimes charging accumulators and at others directly connected with the lamp circuit. But, hitherto, there have been certain drawbacks to this combination of apparatus. Great variations in the speed of trains produce interruptions of the current in the mains, even if a constant potential dynamo and automatic cut-off be used, and if this current is allowed to pass to the lamps, even when a battery of accumulators is in parallel with them, an uneven lighting is the result. It is well known that until a voltage has been attained in the dynamo at least equal to that in the charged, or partially charged, accumulator, it will be futile to complete the circuit, and that if the dynamo circuit is completed the voltage at the accumulator terminals will rise.

In the Vicarino system the above difficulties seem to have been very successfully overcome.

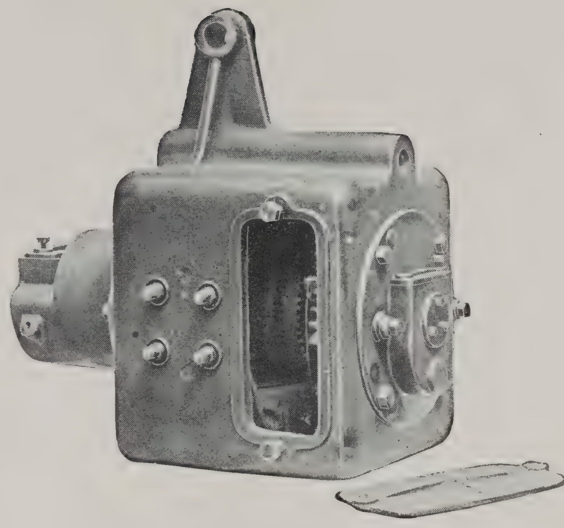
This system, the sole agent for which in Great Britain is the Sun Electrical Company, of Charing Cross Road, London, consists essentially of: An automatic current inverter, combined with a dynamo; a battery of accumulators fixed to the under frame of the vehicle, and an automatic switch disposed between the dynamo and the accumulators.

The dynamo, provided with a suitable casing, is fixed by means of a suspended articulated joint to the under frame of the carriage, and is driven by elastic friction by means of a pulley formed in two parts and keyed upon the axle of the vehicle, such pulley being adapted to act against a friction wheel or the

like of leather or other suitable material fast upon the shaft of the armature, but the desired power may be transmitted by belt, gearing or the like.

The rocking frame which carries the dynamo is traversed by a screw-threaded rod, around one end of which is wound a spring controlled by suitable nuts, the tension of which spring, while variable at will, determines the friction of the pinion upon the pulley.

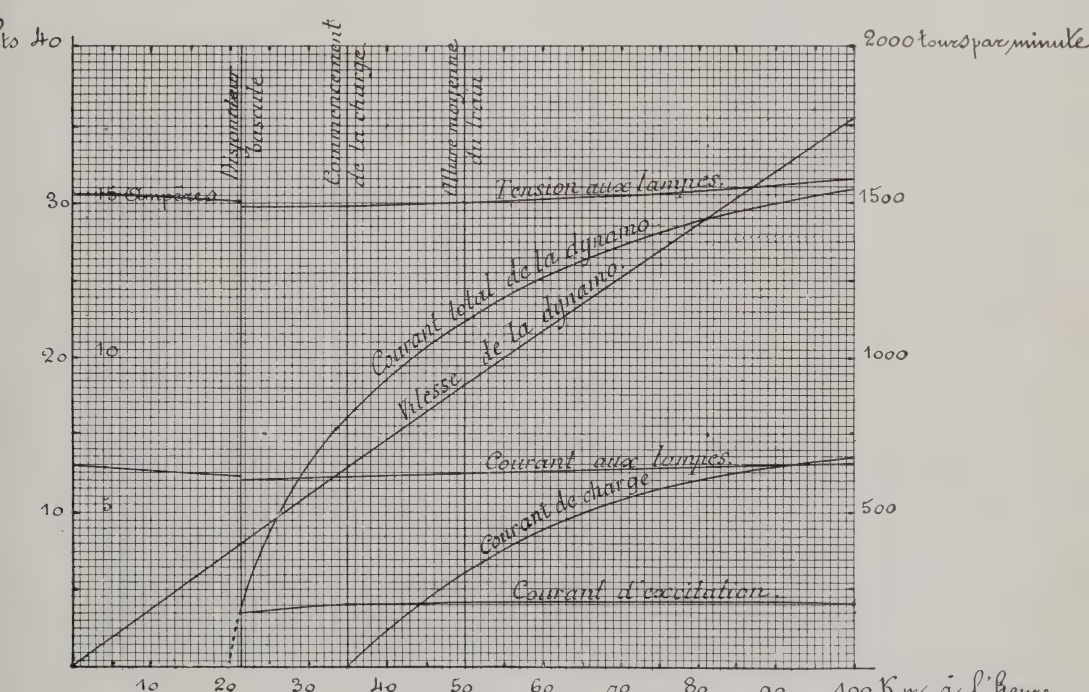
The field magnets are furnished with two windings, one of which is of fine wire for the secondary current from the armature, while the other is of thick wire for the primary current.



VICARINO ENCLOSED DYNAMO FOR CARRIAGE LIGHTING.

The former excites the dynamo and generates the current, while the latter demagnetizes the field magnets. The differential action of the two windings is combined in such a manner as to practically maintain the tension of the dynamo constant for the various speeds.

In order that the dynamo may revolve in the one or other direction while yet producing a current in the outer circuit having a uniform direction, the carbon



EFFICIENCY CURVE OF VICARINO DYNAMO FOR CARRIAGE LIGHTING.

brushes thereof are fixed to the brush-holders, which latter are mounted loose on their gudgeons, and are held in contact with the collector. These brushes and brush-holders are all together fixed to a metal disc mounted loose on the shaft of the dynamo, in such a manner as to be moved in the direction of rotation imparted to the armature by the friction of the brushes upon the collector and by the disc upon the shaft. The stroke of the said disc is limited to 180° by suitable stops and tappets, so that the brushes are displaced for half a circle when the direction of rotation is reversed, and then remain in such position whilst the same direction of movement is continued.

The gudgeons of the brush-holders are each connected by flexible insulated cables to the pole terminals, hence it will be understood that whether the dynamo revolves in one direction or the other the current transmitted to the external circuit always flows in an uniform direction. This current serves to feed the lamps and to charge a battery of accumulators.

To this end the dynamo is connected with the accumulators and lamps to the other apparatus in connection therewith, while the other pole is connected with the thick wire of the field magnets and with an automatic switch.

This switch consists of a vertically-disposed double-wound solenoid, having one of its wires—the thin wire—connected with the terminals of the armature, whilst the thick wire is traversed by the primary current.

This solenoid is furnished with a soft iron core of tubular form which at its upper end terminates in a cup filled with mercury, while to the lower end of the core is secured a rod adapted to dip into a similar cup of mercury.

A metal rod fixed to the upper part of the coil dips into the cup at the upper end of the core when this latter is drawn in by the action of the solenoid. The current from the dynamo flows through the coarse wire of the switch, the metal rod fixed to the coil, the mercury cup and the core, and divides into two circuits: the one parting direct from the accumulators and the other flowing through the resistance and feeding the lamps. At this moment the two windings act in the same direction, the action of the coarse wire being added to that of the fine wire.

If, on the contrary, the dynamo is stopped, or if it gives a current of lower tension than the accumulators, the core descends by its own weight, the rod is no longer in contact with the mercury of the cup, and another suitably arranged rod in opposition dips into the lower mercury cup; the dynamo is then no longer in communication with the accumulators, and these latter feed the lamps, and the resistance is placed in short circuit.

The dynamo revolves at a variable speed, and excites of itself by derivation the action of the automatic inverter, places the brushes with regard to the collector in such a position that the direction of the current produced remains constant whilst the dynamo is at rest; and while it supplies a lower tension than that from the accumulators these latter only feed the lamps.

Directly the tension of the dynamo becomes superior to that of the accumulators the core is drawn inward by the action of the solenoid of the interruptor.

The current of the dynamo passes through the coarse wire of the field-magnets, demagnetizes the dynamo, and maintaining its tension in equilibrium, it passes through the coarse wire of the interruptor and increases its attraction upon the core, feeds on the one hand the accumulators direct, and on the other hand the lamps in passing through the resistance.

If the speed of the dynamo is accelerated, its tension has a tendency to increase, the intensity of the current in the accumulators increases and demagnetizes the dynamo. As, however, the resistance of the accumulators is very weak compared with that of the lamps, the accumulators will be charged while the tension of the lamps remains practically constant.

From this it will be seen that, according to the speed imparted to the dynamo, the current for charging the accumulators varies, while the tension of the lamps and their intensity remains constant.

We have dealt with this system at some length, for though it is now used on many of the leading Continental railways, it is yet practically unknown in this country.

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SOME INTERESTING ELECTRICAL MACHINERY.

THE majority of our readers are probably aware there now prevails the greatest boom in electrical machinery of all kinds that has ever been known. The demand is enormous; and it is at a time like the present that the manufacturing engineer, if he be up-to-date, particularly feels the benefit of having his works equipped with modern tools and lifting and carrying machinery of the most labour-saving description. For although orders are plentiful, prices are keen, and the manufacturer must not only be able to supply, but that at the right price. A very modern manufacturing electrical firm, The International Electric Company of Liege, has just opened an office at Clun House, Surrey Street, Strand, under the management of Mr. E. Kilburn Scott, M.I.E.E., A.M.Inst.C.E. (who will be known to readers as a contributor to this review), and it is to some of their productions that we now wish to draw attention.

When at the Paris Exhibition last year, we were particularly struck with an exhibit of this firm, namely, a 1,000 kilowatt three-phase generator. The working of this generator was all that could be desired, and its rational, as well as elegant, construction was universally admired and appreciated. This firm is now devoting special attention to long distance transmission of power work, electric traction for tramways and railways, and motor equipments for workshop and factory driving. In Fig. 1 we illustrate some 1200 h.-p. multiphase alternator castings, which class of machinery they are now building on a large scale. Fig. 2 shows one of their 125 h.-p. three-phase motors; and Fig. 3, an entirely enclosed motor.

Electricity has completely revolutionised lifting and hauling machinery. By the use of electric motors the lifting and travelling motions are made perfectly independent of one another, so that they can, at will, be worked together or separately. Formerly, to obtain this result with purely mechanical devices, one had to employ complicated gear, subject to constant repairs. All industries nowadays seek to profit by the undoubted superiority of electrical transmission over the older methods of employing steam, compressed air, water at high and low pressure, cables, etc.

Recognising this, the International Electric Company of Liege have made the construction of lifting and hauling machinery one of their special features. In Fig. 4 we illustrate one of their 70-ton travelling cranes used in a quarry, and Fig. 7 shows a crab for an electric overhead travelling crane. With reference to the firm's electric traction work, it is interesting to mention that the first overhead trolley electric car in Belgium was built by this Company. Figs. 5

FIG. 1.—1200 H.-P. ALTERNATOR CASTINGS.

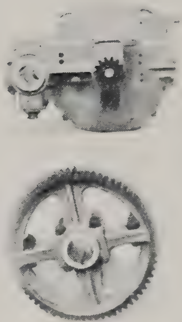


FIG. 5.—GEARED TRAM MOTOR.

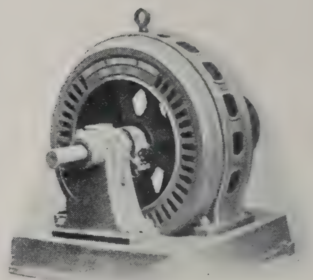


FIG. 2.—125 H.-P. THREE-PHASE MOTOR

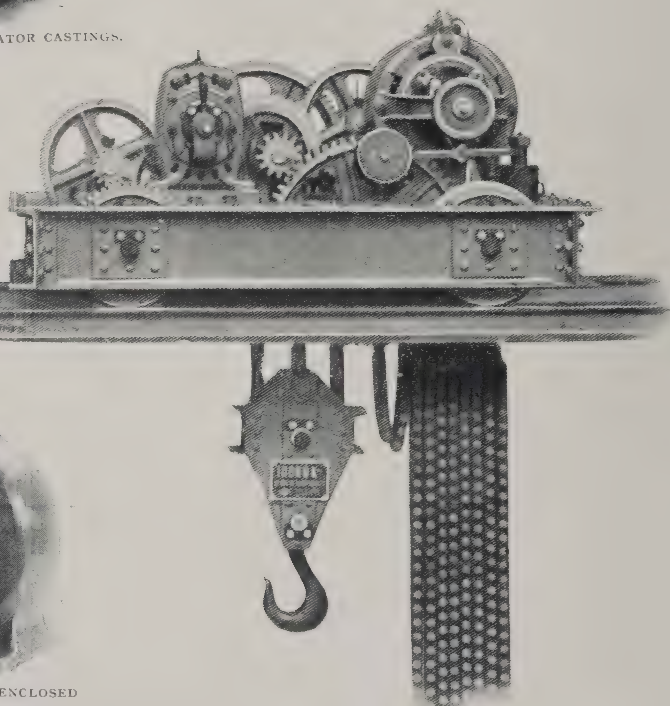


FIG. 7.—CRAB OF ELECTRIC OVERHEAD TRAVELLER.

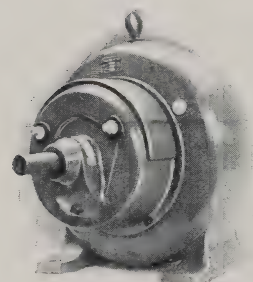


FIG. 3.—THOROUGHLY ENCLOSED MOTOR.

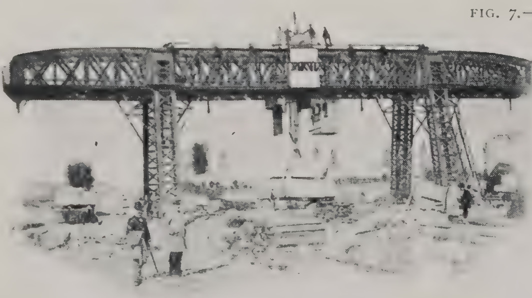


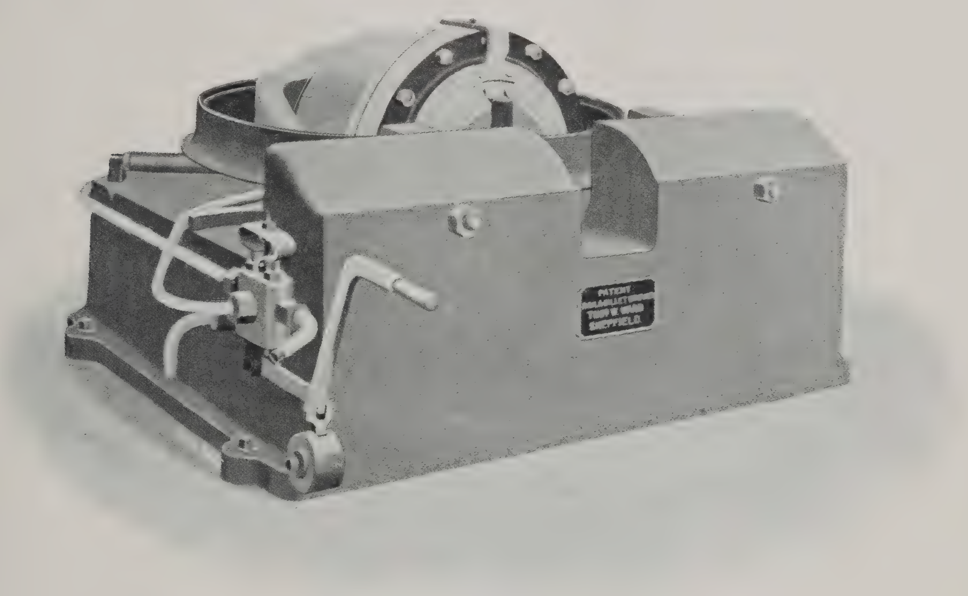
FIG. 4.—70-TON TRAVELLING CRANE IN A QUARRY.

FIG. 6.—GEARLESS MOTOR.

and 6 show traction motors of the firm's manufacture. We might refer also to the company's central power station work, but the space at our command here will not permit of our so doing; except, perhaps, to mention that amongst recent contracts are generating plant of the Hull corporation, Bray Urban District Council, Brussels Municipality, Madrid, Las Palmas, etc. In a future issue we hope to give our readers some details of the interesting machinery here illustrated.

to get out of order, and will handle a large quantity of material at a very small cost.

The breaker for steel rails, hard billets, etc., is similar in design, but lighter in construction, as the power necessary to break a steel rail is less than in the case of a tyre. The machine has been used for cold straightening and bending with great success. Each machine is fitted with suitable valves, the action of which is to cut off the hydraulic supply immediately the article is broken, and return the ram ready for the next break. The rollers are slightly conical and pointing to the centre in the case of the tyre breaker, and cylindrical and parallel in the case of the rail breaker or straightener. Machines are made in various sizes to suit working pressures from 750 lb. to 1,500 lb. per square inch. There is no doubt that this machine is a distinct advance on the old method of shearing or breaking by hand or screw.



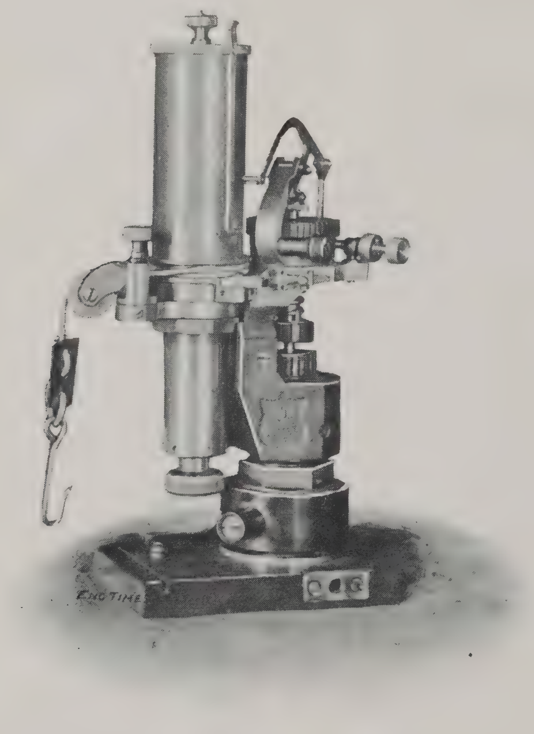
WARD'S PATENT RAIL, BILLET AND TYRE BREAKER.

HYDRAULIC RAIL, BILLET AND TYRE BREAKER.

We give an illustration of a hydraulic rail, billet and tyre breaker made by Mr. Thos. W. Ward, of Albion Works, Sheffield. It will be seen at a glance how compact the machine is. It is constructed more especially for dealing with old rails of old sections, which require to be broken up for smelting, and also large railway tyres of any diameter. The machine is easy of manipulation, has very few parts

THE "M'INNES-DOBBIE" INDICATOR.

SO many central stations' engineers—users of steam engines of various kinds—will be readers of this issue, that we have thought it might interest some to give a few particulars of what we consider to be one of the most reliable and easily-manipulated indicators on the market —the "M'Innes-Dobbie." Its general design and construction will be appreciated from our illustrations, which are so clear as to obviate the necessity of our giving a mechanical description. These illustrations show the makers' latest improved pattern, the principal features of which, in a few words, are as follows:—



THE "M'INNES-DOBBIE" EXTERNAL PRESSURE SPRING TYPE OF INDICATOR FITTED WITH CONTINUOUS PAPER ROLL.

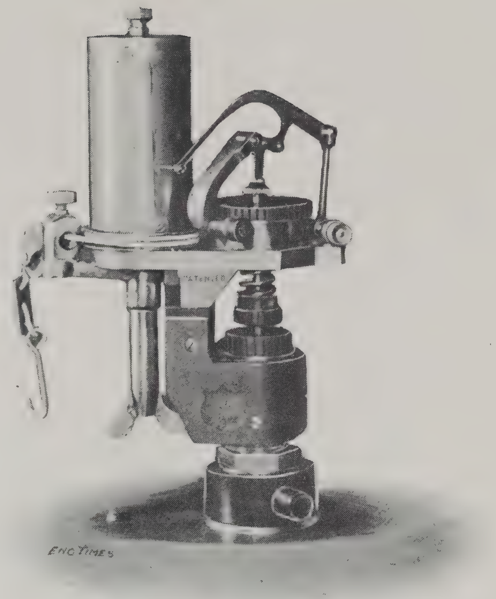
The parallel motion is of improved design, with a central instead of an overhanging pencil arm, the whole movement working in the one central plane, and it is specially constructed to withstand the wear and tear of constant usage without working slack at the joints. The diagram cards can be conveniently and instantaneously fixed to or removed from the drum by means of a double-hinged clip, and are not torn or destroyed in the operation. The tension of the paper drum can be adjusted to suit the speed of engine. Spiral drum springs are supplied, and in the event of breakage the broken spring can be removed, and a new one substituted in a few seconds. The travel of the piston is multiplied six times at the pencil point. The pressure of the pencil on the paper is regulated by means of an adjustable arm sheathed with vulcanite. The cylinder, cylinder cover, and coupling ring are sheathed with a special non-conducting material, to enable the springs to be changed and the indicator handled in comfort. The piston is made of steel, which in practice is found to give better results than gun-metal under high-pressure steam. The cord lead can be carried away at any angle. The cylinder is made open at foot, to permit of cleaning and the easy removal of grit. A clip cord adjuster is fitted on cord, by pressing the tails of which the lead may be lengthened or shortened instantaneously. Patent detent gear for stopping the paper barrel without detaching the cord lead can be fitted when desired.

Great care is exercised in the manufacture of the instruments to ensure perfect accuracy, and every indicator is carefully tested by the makers, Messrs. T. S. M'Innes & Co., Limited, of 41 and 42, Clyde Place, Glasgow, before leaving their works.

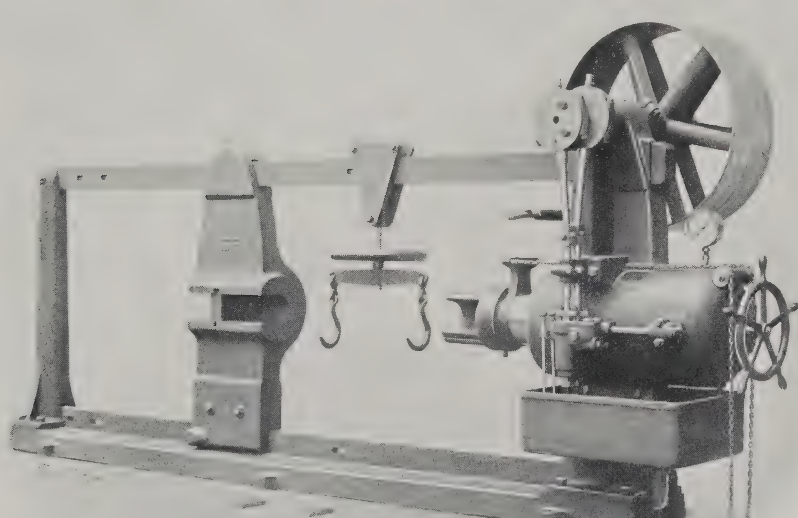
NEW SURFACE CONTACT SYSTEM OF ELECTRIC TRACTION.

A NEW development of the surface contact system of electric traction has recently been brought under our notice by Mr. William Kingsland, M.I.E.E., who has been working at this system for several years. The switches in this process are operated by a positive mechanical action, which, it is claimed, eliminates every source of difficulty and danger arising from the use of an electirc current for this purpose.

The most important feature of the system is the employment of a revolving tappet-wheel, operated by a striker-bar or bars attached to the car. The tappet-wheel is placed in a slot formed in the roadway by means of one of the tramrails and another rail set up alongside it, and into the slot thus formed the striker-bar on the car projects downwards and engages with the tappet-wheel, giving it one-sixth of a turn every time the car passes. The tappet-wheel is connected with the electric



THE "M'INNES-DOBBIE" EXTERNAL PRESSURE SPRING INDICATOR.



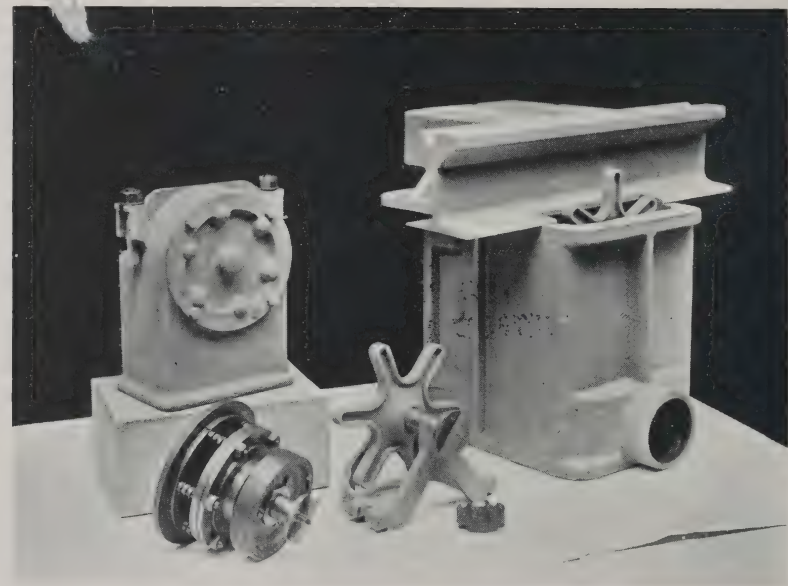
HYDROSTATIC PRESS BY THE NILES TOOLWORKS CO.

(Capacity 200 tons. Distance between tie bars 48 in. Distance between ram and sliding head 8 ft. 4 in.)

switch, and the current is switched on and off the studs in an ingenious manner.

In the illustration will be seen the outer or street switch-box, with a portion of rail, the inner switch-box, the switch and automatic stop, and the tappet-wheel and bracket.

As the tappet-wheel has six arms, and is moved one-sixth of a revolution each time it is operated, there are consequently three "on" positions and three "off" positions of the commutator during one complete revolution, these different positions occurring alternately. The car having two strike-bars, one in front and one in rear, the action on the switch mechanism is accordingly, for the first stroke, to place the switch "on" by giving the sixth of a turn to the tappet-wheel, while the rear striker, by giving it another sixth of a turn, will thus cut the switch "off."



STREET SWITCH-BOX, &C., WITH TAPPET WHEEL AND BRACKET.

The action of the switch will thus be seen to be of the simplest possible kind. It is merely one-sixth turn of a tappet-wheel carrying with it a simple commutator switch. The electric circuit, it should be noted, is never broken on this switch, as the switch in advance of a car is always put "on" before the rear switch is put "off."

When a car is travelling at any considerable rate of speed, the blow struck on the tappet-wheel is a somewhat heavy one, and the momentum of the various parts is liable to carry the tappet-wheel and switch too far round. In order to prevent this, however, an automatic locking device or stop has been patented, by means of which the shock of the blow is taken up by balancing springs, and the switch is absolutely stopped and locked as soon as one-sixth of a turn has been made, being ready a moment after for the next operation.

The Kingsland system does not involve any departure from the present well-known methods of track construction, and it may be applied to any existing track by setting up an outside rail to form the slot with one of the present rails. A recently-constructed experimental line can be seen and inspected at any time at Wolverhampton. Further particulars of this system can be obtained from the Kingsland Electric Traction Syndicate, 8, Breams Buildings, Chancery Lane, London, E.C.

68 B.H-P. "STOCKPORT" GAS ENGINE.

One of four used in the Electric Lighting Station of the Victoria Embankment.

Makers J. E. H. Andrew & Co., Reddish. *Cylinders, 15 in. dia.; Stroke, 22 in.; Speed, 210 Revs. p. m.*

The Engineering Times.

Vol. V. JUNE, 1901. No. 6.

Our Railway and Tramway Number.

We should like to begin this issue with a word of thanks to our numerous friends at home and abroad for their generous praise of our last number. It has been quite impossible to reply individually to the many letters of congratulation that have reached us from readers and advertisers in all parts of the world, and we hope that the writers will accept this slight acknowledgment of their kind expressions, which have been greatly appreciated by us. We also take this opportunity of thanking the many journals, technical and otherwise, which have noticed our last number in their columns. The work entailed in the production of so huge an issue was very great, but the way in which it has been received is extremely gratifying.

The Subway Question.

The nuisance which has been experienced in most of the important towns of this country during the past year or so through the opening up of public footways and roadways, has turned the attention of some municipal authorities toward the idea of subways into which all the different electric light, telephone and telegraph, gas, water, and other supply mains shall be carried. To the average municipal mind, uninitiated in matters of an engineering nature, it is easy to see that the idea would at once commend itself as the best thing in the world to suggest. For new towns or new streets, no doubt, it may be worth considering; but in the case, say, of a city like London, Manchester, Liverpool or Glasgow, the cost would work out at many millions of pounds, the inconvenience we had almost said at millions more, and even after the whole Utopian scheme were planned, the advantages would have to be seriously weighed against some very real disadvantages. The views of the city electrical engineer of Glasgow, as recently expressed by him before the local section of the Institution of Electrical Engineers, must have opened the minds of many to the real nature of the problem. Mr. Chamen says that while the subway idea is certainly very fascinating, the engineers in charge of the several interested departments held very varying views about the proposal. Gas engineers objected that the tunnel might become accidentally filled with a highly dangerous explosive mixture of gas and air; and water engineers pointed out that in the case of a large water main bursting—an accident which would happen occasionally, in spite of all precautions — matters would be in a serious state inside the tunnel. There was also the question as to how access was to be provided for such unhandy articles as 9 ft. or 12 ft. lengths of cast-iron pipes 4 ft. in diameter, and also the question whether the tunnel was to be

made sufficiently large to accommodate a railway for the purpose of conveying such goods for repairs, etc.

* * *

Compressed Air Traction.

The adoption of electricity for street car propulsion has become so general throughout the country, that other systems do not appear to be able to get a mere look in. Steam cars are in operation in a few towns, it is true, but these, or at any rate the majority of them, are already taken under the wing of the electrical promoter, whose main intentions lie in the direction of trolley conversion just at the very earliest moment that things are ready for the change to be made. As regards the running cable method, this is in service on a very extensive scale in the city of Edinburgh; but there has been by no means immunity from mishap, and suggestions have sometimes been made for converting the cable conduit into an electrical one. It may be years before such a change is actually brought about, but if we regard American practice and examine the present day tramway statistics with those of a few years ago, we shall find that over and over again the cable has made way for electricity. Perhaps the most noteworthy instance of this sort of thing is to be found in the conversion of many miles of cable line belonging to the Metropolitan Street Railways Co., of New York, to electric conduit traction. This Company, we believe, employs several methods of propulsion on several different sections, and its most recent experiments have been made with compressed air cars on the Twenty-eighth Street cross town line. One of our American electrical contemporaries is at a loss to understand on what grounds such an experiment [illegible]ld be thought necessary, and has a [illegible]l to say about the great danger [illegible] "each car of which is a veritable charged mine in itself." Presumably, however, the Company has good reason for what it does, although it may not be at once apparent to the mind of the electrical engineer. The peg upon which the comments referred to are hung, is the explosion of the tank on one of the cars on March 27th, the accident "scattering bolts, rivets, scraps of iron and glass in every direction." This appears to have been due to a small steam pipe, which passes along the bottom of the heater, to which it is secured by studs. This pipe, whose steam heats the water, worked loose from the studs, and in the course of time wore the bottom of the heater thin by its continual chafing and grinding. The wall of the heater was in this way weakened, and it gave way, causing the explosion. It is of course conceivable that with crowded cars operating upon crowded city streets serious results might ensue, but one such mishap, although it cannot fail to tell against the system, is insufficient for condemnation thereof *in toto*, at any rate in suburban thoroughfares. No doubt the Company will still go on with its investigations into the merits of the system. It is hardly likely that any special attempt will be made to try it on this side of the Atlantic at the moment, but certainly the New York trials are worth watching.

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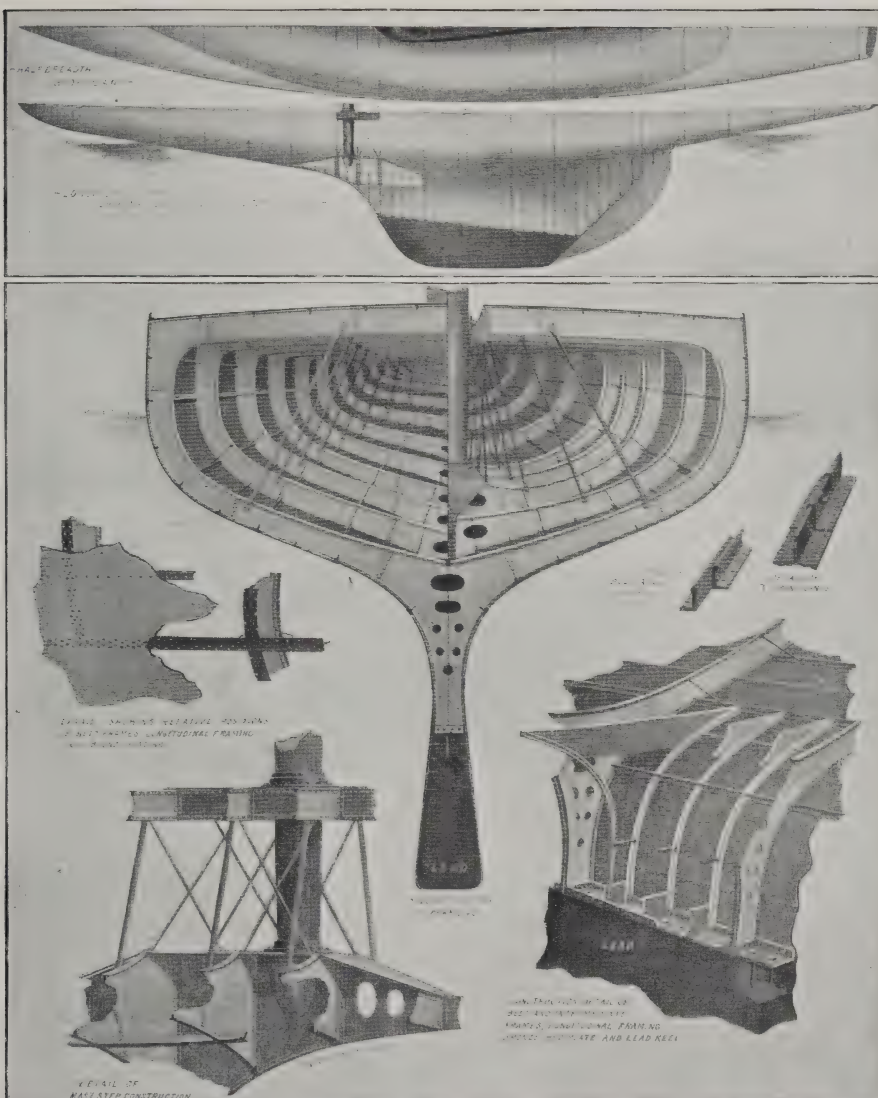
The America Cup Defender "Constitution."

The approaching contest for the America Cup will be followed keenly on both sides of the Atlantic, and not the less so after the regrettable mishap to *Shamrock II.* The *Constitution*, the yacht on which America is relying to retain the Cup, may be described as a high-powered *Columbia*, with the same sheer plan, the same draught, a lighter hull, more lead, and exactly a foot more beam than the *Columbia*. She has

less dead-rise than the latter yacht, a flatter floor, and also a harder bilge. As the result of these combined improvements, all tending to the one object of increased power, she carries about 10 per cent., or about 1,300 sq. ft. more sail than the *Columbia*. Her dimensions are as follows: Length over all, 132 ft. 6 in.; length on water-line at normal draught, 89 ft. 9 in.; beam, 25 ft. 2½ in.; normal draught, 19 ft. 10 in.

We are enabled in this number to reproduce from the *Scientific American* an authentic set of drawings of the *Constitution*, much of the increa^ power of which may be attrib^ improved methods of const^ which the same streng^



VIEW SHOWING DETAILS OF CONSTRUCTION OF THE CUP YACHT "CONSTITUTION."

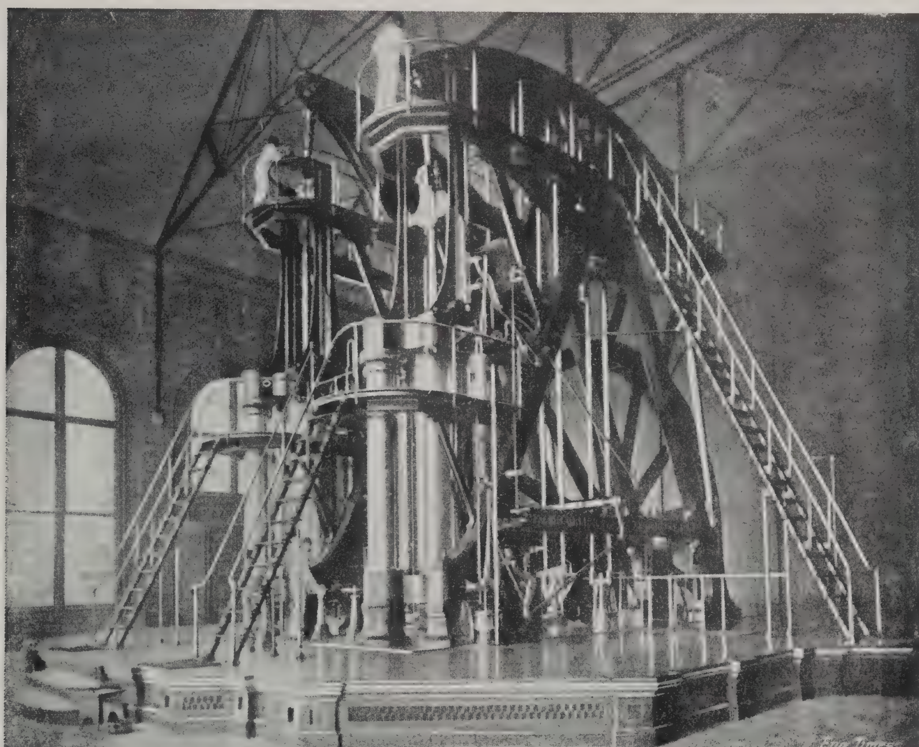
hull is secured with the use of less material. The considerable lightening of the hull of the *Constitution* (which has been accompanied by a decided gain in strength) has been secured by a radical change in the method of framing. Herreshoff's innovation consists in running the framing of the yacht in both directions, using deep belt frames of a I-beam section for the transverse system of framing, and associating them with a system of longitudinal T-bar and angle-iron framing, which serves at once to take up a large proportion of the longitudinal strains which ordinarily fall upon the plating, and so enables the weight of this plating to be very materially reduced. The transverse belt frames and the longitudinal framing are so arranged with regard to the width and lengths of the plating that the butt joints meet upon the frames, and the seams follow the longitudinal T-irons, thus doing away altogether with the weight of the washers and liners necessitated in riveting up a boat built in the conventional way. Judged from an engineering standpoint, this is a far more scientific distribution of the material to meet the special strains to which the hull of a yacht is subjected, particularly in a seaway.

Amending the Light Railways Act.

As we pointed out in our last number, the Light Railways Act has not fulfilled all that was originally expected of it, and it may interest our readers to know what action the Tramways and Light Railways Association has taken with regard to obtaining modifications in the Act, which is now before Parliament for renewal. On February 28th last a deputation was received by the President of the Board of Trade from this association, represented by the Law and Parliamentary Committee and one or two other of the members. This deputation laid before Mr. Gerald Balfour a number of suggestions to be embodied in the new Light Railways Act, at the same time detailing their opinions on the various points submitted. It was contended that applications under the Act should not be refused a hearing on the ground that the proposed light railway lay wholly in a single urban district. It was further suggested that the Board of Commissioners should be made a permanent paid body, and that their numbers should be increased; that the Act should not be regarded as incorporating any of the provisions of the Tramways Act, 1870, or as making any of the provisions of that Act applicable to any Order promoted thereunder; that the Commissioners should have power to allow land to be taken compulsorily for the purposes of constructing a road over which the light railway is to run; that they should also have power in suitable cases to grant compulsory running powers subject to section 23 of the Act; that provisions should be inserted enabling them to authorise statutory companies to raise additional capital and subscribe to light railway companies and to be represented therein, and *vice versâ;* that questions of speed should not be dealt with in the Order, but left to the Board of Trade inspector hereafter; that no local inquiry should be essential to an amending Order, and that inquiries into unopposed Orders might be held in London.

It is hardly necessary to say that the views put forward by the different speakers of the deputation had been carefully considered beforehand, and it was felt that the amendments suggested were only fair and reasonable. It was understood that the views of the deputation should receive every attention, but it is much to be regretted that the President of the Board of Trade has not seen his way to include more of the suggestions of this association in the new Bill. The idea seems prevalent in some quarters that as yet sufficient

experience has not been obtained to enable a permanent measure to be satisfactorily drafted, and it is therefore proposed to do little more than prolong the Act for another five years in its present form. It is doubtful, however, whether the majority of those competent to judge on the question agree with this, and before the new Bill is passed it is hoped that all those who are in any way interested in tramway and light railway matters will do their utmost to bring the necessity before Parliament of inserting further modifications in the new Light Railways Act than appear in the Bill as at present drafted.



THE FAMOUS "CORLISS" ENGINE, ERECTED BY G. H. CORLISS TO SUPPLY THE MOTIVE POWER FOR THE CENTENNIAL EXPOSITION, PHILADELPHIA, 1876.

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A Famous American Engine.

One of the most famous of the world's engines is that which was erected by George H. Corliss to furnish the motive power for the Centennial Exposition, held at Philadelphia in 1876. Since that date other engines of greater power and of more modern design have been constructed, yet, in spite of this, the famous Centennial engine remains to-day a living example, if we may so phrase it, of the genius and courage of George Corliss, in whose fertile brain it was conceived. Regarded at first as a "white elephant," and derided by many who called attention to the unlucky fate of the steamship *Great Eastern*, and prophesied similar things of the "Corliss" engine, the latter has so far justified its existence that at the present time, after over twenty years' continuous service, it is working from ten to twenty-four hours daily, and with an economy which many of the more modern engines would find it extremely difficult to equal.

Our Chicago contemporary, the *National Engineer*, gives an interesting description of this engine in its last issue, from which we take the following particulars. The engine is a simple condensing one, with the "Corliss" valve gear and cut-off adapted to a vertical engine. It took seven months to build, and when installed at the Exposition, it was set in motion by President U. S. Grant. The late Dom Pedro, Emperor of Brazil, was also present, and was deeply interested in the engine. After watching the revolution of the great flywheel for a few moments, he quietly remarked, "This beats our South American revolutions."

At the close of the Exposition the engine was taken back to Providence, where it had been built, and in the year 1880 it was bought by Mr. George M. Pullman, requiring a train of thirty-five cars to take it to the purchaser. In the following year it was started at the Pullman car works, amid great enthusiasm, in the month of April. The engine has been running successfully there since that date; its total weight is 700 tons. The engine-room is 84 ft. square and 68 ft. high, and the platform upon which the engine stands is 26 in. above the floor of the room. The frame and large parts were first set up, and the building erected around them. The diameter of the large gear flywheel of the engine is 29 $\frac{7}{10}$ ft.; the width of its face, 24 in.; the pitch of the gear, $5\frac{1}{8}$ in.; and the number of the teeth is 216. This massive wheel is built up in twelve segments, and weighs 56 tons; it revolves 36 times a minute. The total number of revolutions made by this great wheel during the Philadelphia Centennial Exposition was 2,355,300. The engine was rated at 2,400 h.-p. by the builder, yet it has developed 2,500 h.-p., though it is seldom required to work beyond its actual capacity. The water used in condensing the steam during one day's run of the engine amounts to about 300,000 gallons. Although, naturally, repairs have been occasionally necessary, the engine now seems to be in as good condition as when first started. It is greatly admired by visitors from every country of the globe.

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Self-Propelled Traffic.

An important series of trials of motor vehicles for heavy traffic is being held this month by the Liverpool Self-Propelled Traffic Association. The object of these trials is to provide a means of making a preliminary test of types of heavy motor waggons suitable for haulage operations in Lancashire, prior to their being taken over by a Lancashire syndicate, which will be formed for the purpose of conducting road transport between Liverpool and manufacturing towns in Lancashire. The association previously arranged with Lancashire manufacturers and Liverpool shipowners for the provision of loads of general merchandise, the latter being collected, transported and delivered free of charge, in order to demonstrate the practical and commercial qualities of the system.

At present, the limit of three tons tare under the Locomotives on Highways Act, 1896, is the great drawback to the undertaking of really heavy work by automobiles, and the memorial of the Automobile Club to the President of the Local Government Board will be supported by a second powerful memorial praying for the same modification of the 1896 Act, viz., the substitution of a maximum weight per inch width of tyre per wheel for the rigid limit of three tons as the total tare weight of any vehicle.

An interesting address on this subject was given recently before the Liverpool Chamber of Commerce by Mr. E. Shrapnell Smith, who pointed out that in order to see whether manufacturers

could improve their designs so as to produce an efficient vehicle under the three-ton limit of tare, the Liverpool Self - Propelled Traffic Association decided to allow an interval of two years between their second and third trials. The result had been that all the vehicles have grown heavier, and there is now another strong argument in favour of the desired increase. As a tentative clause in the Act, that controlling the tare has served its end of forcing manufacturers to put forth their best efforts in design and workmanship; but Mr. Smith considers it hard to imagine why the tare weight should not have been equal in the first instance to at least that unit of traffic which the motor vehicle replaces, viz., a lorry and three horses weighing, say, four-and-a-half tons. Of course there was no experience of this type of vehicle in 1896, seeing that only light pleasure carriages of foreign build and traction engines existed.

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Government Enterprise.

It really seems too outrageous an anomaly that the Board of Trade, a Government Department, should continue using its official position to obtain advertisements in competition with journals run by private enterprise. In its latest advertising letter, *The Board of Trade Journal* ("edited by the Commercial Department of the Board of Trade") is so keen on obtaining business that it is reduced to cutting its rates, and even offers to insert an advertisement, at a minimum space, at a shilling per insertion. This is competition indeed, and we should tremble for our very existence were we not quite aware of the fact that even such an inducement as this will be hardly likely to tempt advertisers in engineering papers to take advantage of it.

Railways in Western Australia.

The report on the working of the Western Australian Government railways and tramways for the year ended June, 1900, a copy of which has been sent to us, contains several interesting particulars. The length of the various railways in the colony open for traffic at that date came to a total mileage of 1,355, though we note that for the first time since 1891–2 no new railways have been opened during the past financial year. The total earnings by these railways for the year amounted to £1,259,512, the corresponding expenditure being £861,470, leaving a credit balance, after paying working expenses, of £398,042. The net credit balance, after deducting interest charges on capital expenditure, etc., works out at £162,066.

Attention is drawn in the report to the want of adequate workshops accommodation at Fremantle, in consequence of which the operations of the locomotive branch are severely hampered. The general manager of the railways strongly urges the necessity which exists for the erection of new shops being put in hand without delay. The total number of vehicles on the books of the department at 30th June, 1900, was:—Locomotives, 233; carriages, 259; brake-vans, 107; waggons, 4,671. These represent a total capital expenditure of £1,322,915.

Purchase of rolling stock at an estimated cost of £216,050 is recommended to meet requirements to the end of the year 1902.

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Refreshing Optimism.

There is a very striking article in the current number of the *Nineteenth Century and After*, by Mr. Andrew Carnegie, on the subject of British pessimism in trade and commercial matters generally. Mr. Carnegie is known to everyone on both

sides of the Atlantic as one of the most successful business men of the day, and his paper is a very important and weighty contribution to the discussion of a question which becomes more acute and pressing every year. Mr. Carnegie knows what he is writing about. He is thoroughly familiar with every aspect of American as well as with British trade and workshop practice, and there is probably no one who is better qualified to pronounce an opinion on the present position and future prospects of British trade than he. Mr. Edison has recently delivered himself of a jeremiad upon British characteristics and methods, and has prophesied lugubriously as to the trade prospects of this country in the present century, and it is consequently decidedly refreshing to have what is on the whole a distinctly optimistic view of affairs from so keen and practical an observer as Mr. Carnegie. We do not mean to imply that, in the opinion of Mr. Carnegie, there is no cause for alarm. "The reader must," he writes, "adjust himself to present conditions, and realise that there is no use in these days dwelling upon the past; and especially must he cease measuring his one country with the forty-five countries of the American Union, *E pluribus unum*." It is out of the question, he holds, to compare 41 millions of people upon two islands, 127,000 square miles in area, with over 500 people per square mile (England and Wales), with 77 millions upon $3\frac{1}{2}$ million square miles unequalled in natural resources, with only 30 people per square mile. It is in aggregate wealth only that Great Britain has been left behind by the United States, and yet, "with nearly double the population," the American Union "has only one-fifth more wealth in the aggregate," and consequently individual wealth in America bears no comparison with that in the United Kingdom. "Even in credit there is only the United States whose credit is better, as shown by the prices of its bonds; but were it to go one-half the distance on the road to financial troubles which Britain for years has traversed, it is improbable that even she could borrow upon the terms of the last addition to the British debt. Primacy in credit may yet be regained."

In certain branches of trade, such as mining, weaving, and electrical machinery, we are ready to admit that British supremacy does not exist, but alongside this we would place the fact that our shipping "still exceeds that of any nation twice over," and Great Britain's ascendancy in this respect is so decided that Mr. Carnegie does not expect that any man living is likely to see it overcome. But his view is otherwise when he turns to shipbuilding, and he urges that Britain must not fall asleep, for "America, with her cheap steel and timber and surprising workmen, is finely equipped," and adds that "if Britain hold supremacy, she will richly deserve the prize." Mr. Carnegie then proceeds to answer the oft-asked question, "Is British foreign trade declining?" He considers that disputants forget that the matter has two parts. "Exports are one branch, imports another; the former has decreased *per capita*, and the latter increased. The two combined show that British foreign trade is not declining."

Studying the subject carefully, and avoiding the tendency to generalise from temporary causes and values covering only this year or that, the writer is satisfied that the true answer to the question, "Is British trade declining?" is that it cannot be affirmed to be either declining or increasing, imports and exports combined. It has apparently reached its limit, and is not expanding, having remained practically stationary for, say, ten years.

Mr. Carnegie draws attention to the

fact that taxation in this country is far heavier *per capita* than in Germany or America. He considers that here is a real danger, as the burden imposed by the Government handicaps trade: "After British employers and employed reach the American standard of economical production Britain will still remain heavily handicapped in the industrial race by the enormous load of taxation under which her producers labour as compared with America. It seems to the writer that this should be one, if not the chief, controlling factor in determining the world-policy of the nation. It must soon force itself upon statesmen."

While holding that the financial and political situation, as he sees it, is alarming, he states: "The qualities of the race lie dormant, and are still there—the dogged endurance, the ambition to excel, the will to do or die, are all there, but it has not been necessary to drill them into disciplined action. Let serious disaster come in industry or war; let British trade really be captured by others, and decline to the point of closing mills and bringing home to employer and employed that it is change or ruin; or let the sceptred isle be invaded and the hitherto self-satisfied amateur officer see in his army life not a fashionable pastime, but a serious profession like that of the navy, and the soldier that he has rifles instead of spears to face, and it is do or die for the salvation of his country, and the world will then see—but perhaps not till then—what wonders the race can still perform when it fights, not for shadowy paramountcy over others, but for home and country." To all of which we heartily subscribe.

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Specialisation in Public Schools.

We publish in this issue the concluding portion of the interesting address by Dr. Henry T. Bovey on "The Place of Science in Education." It is unnecessary for us to discuss Dr. Bovey's remarks at any length, but there is just one point upon which we should like to make a few comments. In dealing with the vexed question of specialisation, the President of the Canadian Society of Civil Engineers endorses the view which is held by many of the most prominent educationists, that "the best training for a special sphere is that which will give the mind the largest grasp of which it is capable"; in other words, that young men are not losing time "when not directly preparing for some special sphere." On the whole we are inclined to agree with this, but, although there are signs of an awakening to modern requirements, the fact remains that the majority of the principal English public schools still *specialise* in classical literature, and headmasters continue to look with suspicion upon any change in the curriculum that will result in less time being devoted to Latin and Greek. In public school entrance examinations a most disproportionate importance is attached to classical attainments, and the consequence of this is that the preparatory schools which send in candidates for these examinations arrange their syllabus of instruction accordingly. The result is that young boys spend an unconscionable amount of time over Greek roots and aorists, and when they go to a public school they not unnaturally manifest a preference for those studies—the classics—in which they have been most thoroughly grounded, and in which they are therefore able to do best. This is why the modern sides at many public schools to-day lack the popularity which should and would be theirs if school entrance examinations were reorganized on a different basis.

RUNS ON HIGH-SPEED LOCOMOTIVES.

By Ben. H. MORGAN.

WE have heard so much lately about "slow British Locomotives" and the way in which America and France are "leaving us behind" in the matter of railway speeds, that it might not be uninteresting to some of my readers to place on record here a few of my recent experiences on the footplate. Not that the speeds which I have to give are in any way remarkable, but the conditions under which they were made might help readers to appreciate to a higher extent the capabilities of the British engine. Writers in the daily press do not seem to realise that a considerable increase in our railway speeds means the straightening out of curves, the strengthening of permanent way and bridges and viaducts, while these considerations do not weigh to nearly so great an extent with America and France. They also overlook the important fact that on the majority of our main lines trains run to schedule time—my experience has taught me that this is not so much the case in France or America. Their time-tables read well, but are not closely adhered to. France has a few trains faster than we have covering fairly long distances, but our average for fifty miles and over is far and away better than anything France can produce. This is not a matter of debate, but common knowledge to the traveller. In America it is different. Speeds are undoubtedly higher there, but, then, they do not labour under restrictions as to weight, height, etc., in engine building as do our engineers in this country.

But I will not enter further into the discussion on the relative merits of British and foreign locomotives, as the subject was so fully dealt with in the last issue of this Magazine by much abler authorities than myself.

The runs described in this article were not specially arranged in any way. I had permission from the various locomotive superintendents over whose lines I travelled to board any engine I cared to. The speeds here recorded, therefore, are quite ordinary, and, in some cases, possibly below the average. It will thus be seen that the British locomotives do not hold an inferior position in the matter of speed after all. They make no fuss about moving a 350-ton load at a mile a minute, and on some of the runs here referred to, over favourable strips of road, speeds of from seventy to seventy-five miles an hour were maintained. All the engines described in this article work their trains every day over some portions of their journeys at over sixty miles an hour.

York to Newcastle.

A splendid example of British practice is shown in my first illustration. It is the latest type of express passenger locomotive designed by Mr. Wilson Wordsell, locomotive superintendent of the North Eastern Railway.

These engines are purposely built for working the heavy East Coast express passenger traffic between York and Edinburgh. They are six-wheeled coupled with a four-wheeled bogie in front. The coupled wheels are 6 ft. $8\frac{1}{4}$ in. in diameter. The cylinders are placed

outside the frames, and are 20 in. diameter, with a stroke of 26 in. The barrel of the boiler is 15 ft. $10\frac{1}{2}$ in. long and 4 ft. 9 in. diameter outside. The firebox is 8 ft. long, with a grate area of 23 sq. ft. The working pressure is 200 lb. per square inch. The engines are designed to work trains equal to twenty carriages loaded, and to run $124\frac{1}{2}$ miles at 53 miles per hour without a stop. The weight of the train behind the tender will vary from 350 to 375 tons. It will thus be seen that the work these engines are required to do is of the heaviest and fastest description.

On the 26th February last, at York, I got on the footplate of engine No. 2001 (see Fig. 1), with Driver J. J. Pickering in charge. We were to work the two o'clock Scotch express through to Newcastle without a stop, a distance of $80\frac{1}{2}$ miles. The weight of the train was nearly 300 tons. Starting punctually at schedule time, the engine took charge of her load with the greatest ease, and within a few minutes of leaving the station was moving at a mile a minute. On short stretches of the road this speed was considerably increased, but I was unable to correctly record the best single mile we did. Suffice it to say that, running against a stiff wind and over heavy gradients, we covered the first forty-five miles in forty-seven minutes.* This is a phenomenal performance in express working, considering the load and the character of the road, and the reader must bear in mind that this is not an occasional performance, but is now done every day with the Scotch express trains on this line.

No trouble was experienced in maintaining a uniform boiler pressure or in respect to the heating or otherwise of frictional parts. Exhaust-steam combination ejectors (Davies and Metcalfe's patent) are used for boiler feeding, and they appear to do their work most satisfactorily. We arrived within some two miles of Newcastle a few minutes in advance of the scheduled time, but were there, unfortunately, "held up" by a signal, which succeeded in turning our gain into some minutes' loss.

Newcastle to Edinburgh.

At Newcastle I changed on to engine No. 2008 of the same class, which took the train on to Edinburgh. On this part of the road also we did excellent time, averaging over fifty miles an hour, including one stop of five minutes at Berwick. Gradients of 1 in 96 for about five miles and others of 1 in 150, 1 in 170, and 1 in 200 are met with on different parts of the line.

One of the drivers remarked to me, "I can not only usually maintain the schedule time, but have a little to spare." This confidence, in drivers, in the capabilities of the engines under their charge is in my opinion one of the greatest compliments that can be paid to a locomotive superintendent.

Glasgow to Carlisle.

One of my most enjoyable runs was on the Caledonian Railway on one of Mr. John F. M'Intosh's "900" class engines. This splendid engine is illustrated in Fig. 2. Her principal dimensions are:—Coupled wheels, 6 ft. 6 in.; cylinders, 1 ft. 7 in. diameter, with a stroke of 2 ft. 2 in.; working pressure, 180 lb. per square inch; weight of engine and tender in working order, 96 tons. With a heavy corridor train we soon got clear away, and almost as soon as the last carriage had cleared the station the driver began to "notch up," so well did the engine have her load in hand. As most of my readers are probably aware, some exceedingly heavy gradients are met with on this

* Though no attempt has been made to tabulate in proper form the data obtained on these runs, yet the greatest care has been taken to ensure accuracy where speeds are given, the times in each case having been recorded by two "Benson" watches.—The Author.]

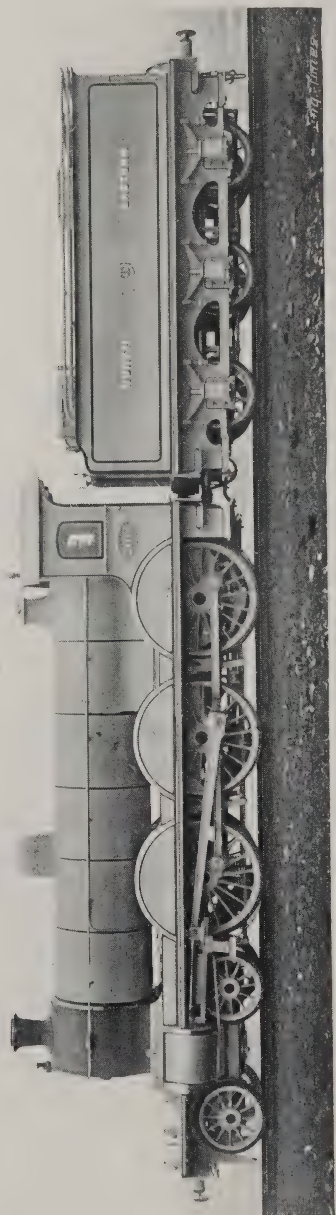


FIG. I.—LATEST TYPE OF EXPRES PASSENGER LOCOMOTIVE, NORTH-EASTERN RAILWAY. DESIGNED BY MR. WILSON WORSDELL, LOCOMOTIVE SUPERINTENDENT.

FIG. 2.—LATEST TYPE OF CALEDONIAN RAILWAY EXPRESS ENGINE, DESIGNED BY MR. JOHN F. M'INTOSH.

line, but this engine negotiated them in splendid fashion. The driver—I have unfortunately forgotten his name—was one of the most expert I have met. He seemed to know exactly what his engine was capable of, and she worked like a watch under his hands. We left Glasgow at 2 p.m., and arrived at Carlisle at 4.13, having covered a distance of 102½ miles. Considering the difficult character of the road and the heavy train we worked, that must be considered a very creditable performance.

Marylebone to Leicester.

On the Great Central Railway Mr. J. S. Robinson, locomotive superintendent, accorded me runs on two types of the Company's express engines—one a single-driver of Mr. Harry Pollitt's design, and the other a four-wheel coupled type. I boarded the former, No. 967 (shown in Fig. 3), at Marylebone Station on the 15th March last for a run to Leicester, Driver C. Prosser being in charge. We started punctually at 10 a.m., and reached Harrow, 9 miles 19 chs., at 10.15; Rickmansworth, 17 miles, 10.25; Amersham, 23 miles, 10.37, all uphill work; Aylesbury, 37 miles, 10.53; Quainton Road Junction, 44 miles, 11.2. This left, according to schedule time, but 63 minutes for the next 58 miles and 57 chs. We covered it as follows: Brackley, 59 miles 21 chs., 11.19; Woodford, 69 miles 6 chs., 11.31; Rugby, 83 miles 18 chs., 11.45; Leicester, 103 miles 7 chs., 12.5 noon; the steepest gradient between Quainton Road and Leicester being about 1 in 170. This is, I consider, a very good working, taking into consideration the difficult road and weight of train—*i.e.*, nearly 200 tons, for a single-driver engine with 7 ft. 9 in. wheels, on an average consumption of fuel of rather less than 30 lb. per mile. I am rather of opinion that the first 38 miles of road from Marylebone is scarcely suitable for this class of engine, as in some places the gradients are very severe, varying from 1 in 80 to 1 in 120, with very sharp curves and junctions, which cause the speed to be restricted — at Rickmansworth and Aylesbury to 10 miles an hour, and at Quainton Road to 15 miles. I was exceedingly pleased with the behaviour of the engine, and consider it one of the easiest riding engines that I have experienced. That it will do admirable work under the right conditions is shown by the fact that we covered a seven-mile level stretch in 5½ minutes.

Leicester to Marylebone.

At 12.55 I got on the footplate of a four-wheeled coupled engine, No. 865

(driver, W. Chappells), and started on the return journey. Notwithstanding a bad check at Rugby, we did the first 45 miles in $48\frac{1}{2}$ minutes; passed Quainton Road, 58 miles 59 chs., in 66 minutes; Quainton Road to London, 44 miles, in 64 minutes. On the latter section we were nearly stopped at Harrow, and reduced speed at Aylesbury and Rickmansworth. This seemed to me to be the better class of engine for working the Leicester to London road.

London to Cambridge.

To Mr. Holden, of the Great Eastern Railway, I owe one of my most pleasurable experiences on the footplate. On January 10th last, at 9.11 o'clock, I boarded engine No. 1898 (here illustrated) at Liverpool Street She was due to start at that time, and with steam blowing off at 160 lb. away we went. The patient reader's attention is directed to the diagram show ng the gradients we had to encounter. Leaving behind Bishopsgate Street, we negotiated a short stretch of 1 in 70 with the greatest ease, passing in turn Bethnal Green Junction, Cambridge Heath, and other stations until Tottenham was reached. By this time, and under the guidance of Mr. Bell, one of Mr. Holden's able assistants who accompanied me, I had begun to realise somewhat the extent of the progress made by Mr. Holden in burning liquid fuel. But it is unnecessary for me to go into the subject here, for the reason that Mr. Holden has himself dealt with his system in my last number. Some few impressions, however, might not be uninteresting. Perhaps the first thing that forcibly strikes the footplate visitor is the disuse of the shovel, with its accompanying dirty and back-aching labour. How those firemen must bless their superintendent! Instead of having to shovel on coal every few minutes, the fireman has but to regulate with two valves the supply of fuel and draught according to the head of steam he has and requires. Little wonder is it then that with the absence of the dust and work which attends the use of coal-fuel the interior of the cab should be kept "spotlessly" clean. And so it is. In fact it would not be too much to say that so free from dust and dirt is the cab of Mr. Holden's engine that a delicately-attired lady might take a couple of hours' ride on the footplate without soiling her dress.

FIG. 3.—SINGLE-DRIVER EXPRESS PASSENGER LOCOMOTIVE, GREAT CENTRAL RAILWAY. DESIGNED BY MR. HARRY POLLITT.

The changing of some coaches detained us at Tottenham until ten minutes past the scheduled time, and if you refer to the diagram you will see the kind of road before us for the next thirty miles over which we were to endeavour to make up time. But we got away pretty smartly, and soon settled down to good work, the engine standing up to those stubborn gradients in excellent style, easily maintaining her 160 lb. of steam the whole way. When we reached Elsenham, notwithstanding grades of 1 in 107, etc., we had regained two of those ten minutes. The rest of the run, so far as gradients were concerned, was principally in our favour, and so we should have picked up the greater part of the lost time had we not had to reduce speed over a section of the road that was being repaired. As it was, we reached Cambridge at four minutes behind the scheduled time, having gained six minutes since leaving Tottenham. A very strong objection to the use of liquid fuel on steamships is the strong smell which it occasions, and I was curious to observe what the result was in this connection on locomotives. I was agreeably surprised. The combustion in the firebox of engine No. 1898 was so complete that practically no smoke, smell, or residue were given off. And this was not only in the open, but also in the two tunnels through which we passed, where smell could readily have been detected on the footplate had there been any. Mr. Holden has made a distinct advance in locomotive practice, and deserves well of his time.

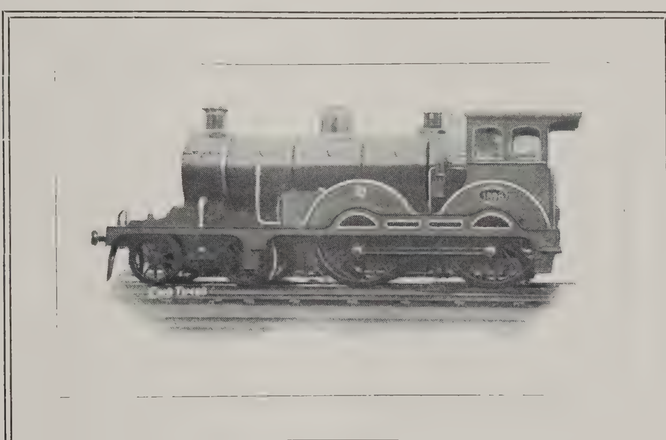


FIG. 4.—TWO-WHEELS COUPLED EXPRESS LIQUID FUEL LOCOMOTIVE, GREAT EASTERN RAILWAY. DESIGNED BY MR. JAMES HOLDEN.

Paddington to Swindon.

I made this run on one of Mr. W. Dean's well-known single-drivers (Fig. 6). The day was a very bad one for fast running, the rails being very greasy, and a strong head wind blowing, just the worst kind of weather for an engine of this type. With a fairly heavy load we left Paddington at 3.15 p.m., and though we experienced a great deal of slipping, we had put on a speed of nearly 60 miles an hour when we reached Acton. Unfortunately for the run, a few miles of the road was being relaid a little distance past Ealing, and over this part we had to reduce speed to 10 miles an hour. Here we lost eight minutes, but notwithstanding the wet rails and consequent occasional slipping,

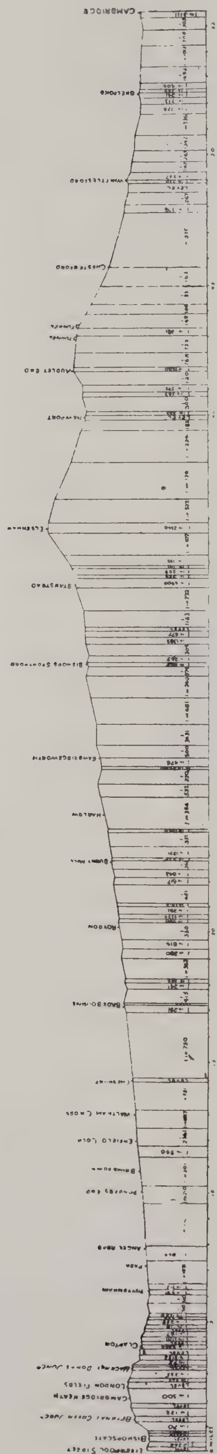


FIG. 5.—DIAGRAM SHOWING GRADIENTS ON THE LINE FROM LIVERPOOL STREET TO CAMBRIDGE.

we were soon getting the time back again, and should have reached Swindon at the schedule time, 4.42, but were delayed by a signal just before entering the station. Notwithstanding the severe conditions, steam was easily maintained the whole distance, and I can now

FIG. 6.—SINGLE-WHEEL EXPRESS PASSENGER LOCOMOTIVE, GREAT WESTERN RAILWAY.
DESIGNED BY MR. W. DEAN.

understand why this type of engine is such a favourite amongst G. W. R. drivers and firemen.

Geo. H. Morgan.

LIGHT LATHES AND SCREW MACHINES.*

By JOHN ASHFORD, A.M.I.Mech.E.

(*Continued from page* 222.)

REGARDING PARAGRAPH (*e*). —Several devices have been introduced for obtaining the double action with one motion. Two of these are illustrated in Fig. 50.

TURRET LATHES.

In the earlier days of engineering, large quantities of similarly turned articles were not, as now, required; therefore, the type of machine evolved at that time was one that could be used for a variety of work, and the chief object sought was general adaptability.

When the need arose for the production of many similar articles at low cost, manufacturers, adapting the machine to their requirements, fitted stops to the slides so that unskilled labour might successfully do the work of turning; but to produce a complete article this often meant a number of chuckings. This system of working may still be found in some factories.

As a further improvement on such a method, the turret form of tool-holder was introduced, and that developed into the type of turret lathe with which we are now familiar. It will thus be seen that the modern turret lathe is purely a development of the turning lathe brought about by the necessities of modern manufacturing. The requirements of this type of lathe have already been set forth in paragraphs (*i*) to (*o*), and will now be further considered.

Chucks for Turret Lathes.—There seems to be some difficulty in designing a chuck which shall comply with all the requirements of paragraph (*i*), especially when the bar to be operated upon is over one inch in diameter. The usual thing is some form of collet-chuck, as Fig. 51, together with which is combined a device for obtaining a mechanical advantage and securing a tight grip. The most favoured method of operating collet-chucks is by the combination of a pair of bell-cranks with a sliding cone. Other methods are by a system of wedges, by modification of the toggle-joint, and by differential screws. The combination of wedges is well exemplified in the Pittler chuck, where there are three wedges arranged in series, together with a rack-and-pinion, Fig. 52.

A powerful chuck of simple form has been adopted by The Wolseley Co., in which toggle-joints are introduced to get a tight grip, Fig. 53.

That applied by Ward (Fig. 54) to their larger type of turret lathes is a combination of toggles very similar to that introduced by Jones and Lamson in their flat-turret lathe.

Alfred Herbert has introduced the principle of the differential-screw in his patent power-operated chuck, which is simple in action, requiring but little effort on the part of the operator, Fig. 55.

The drawing of this chuck, which is a sectional plan, requires some explanation:—Upon the end of the mandrel A

* A paper read before the Institution of Mechanical Engineers.

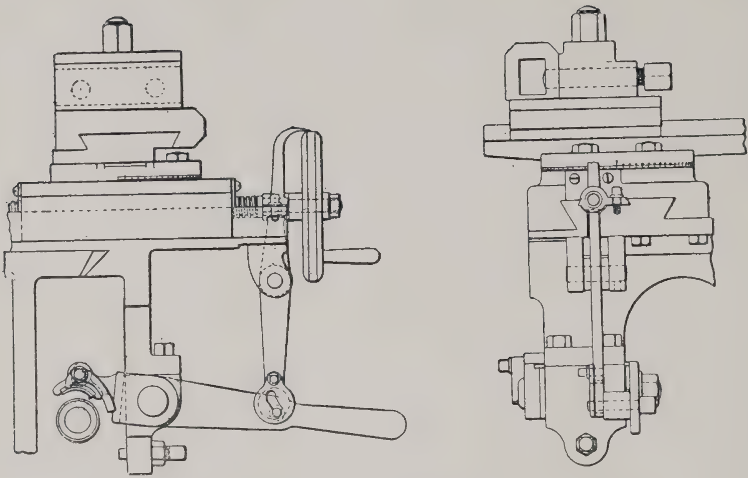


FIG. 50.—COMBINED NUT-RELEASE AND QUICK-WITHDRAW (HUMPAGE, JACQUES & PEDERSEN).

the body of the chuck B is screwed. Its outer extremity is bored to the necessary taper to receive the split collet I, and at its inner end there is an enlarged portion cut with teeth to form a spur wheel at C. This spur wheel continuously engages the pinion D mounted upon the spindle L and free to revolve. Upon D a steel cone E is securely fixed. This forms part of a double cone friction-clutch, the other parts of which are the spur wheel F bored right and left with internal cones, and the cone K which is securely fixed to the casing. The wheel F is firmly mounted upon the spindle L and constrained to move longitudinally as required by a rack and pinion mechanism communicating with an exterior handle. The teeth of the wheel F continuously mesh with those of a wheel G that forms part of a sleeve which is screwed upon the exterior of the chuck body B with a right-handed thread. This sleeve G is also threaded upon its exterior with a right-handed thread of slightly coarser pitch, and upon it is screwed the cap H. It will be seen that if the cap H may only rotate at the same speed as the chuck body, which it is forced to do by the constraint of the small screw M, because the latter passes through the cap into a slot cut in the body B, and also if the sleeve G is caused to revolve at a different speed, the cap H will receive a longitudinal motion in respect

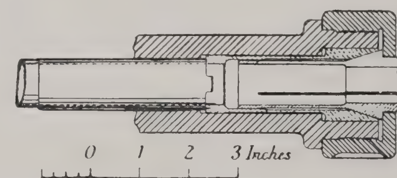


Fig. 51 (Ward).

Fig. 52 (Pittler).

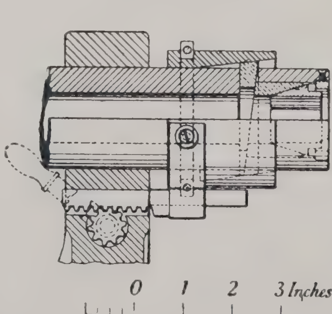
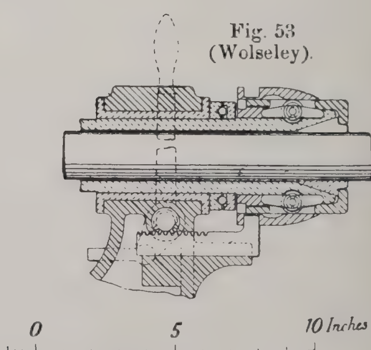


Fig. 53 (Wolseley).



FIGS. 51 TO 53.—COLLET-CHUCKS.

to B according to the difference in pitch of the screw threads upon the exterior and interior of the sleeve G. In this way the collet is closed.

To operate the chuck, the handle is moved so that F is pressed to the cone E, when, as the diameter of wheel F is greater than that of D, the sleeve G will rotate faster than the body B, thus causing the collet I to be forced home by the cap H. On the other hand, if F is pressed to the stationary cone K, the sleeve is held at rest while B and H continue to revolve and the collet is opened.

With this chuck there is a greater range of motion than usual, which makes it possible to use rougher stock. Moreover, for large work, an exceedingly tight grip may be obtained with little effort on the part of the operator.

The chief fault of most of the collet-chucks is, that the actual movement of the collet is small; and, moreover, as they must be moved to a given point to lock themselves, they allow of little variation in the size of the stock used. Consequently, as ordinary rolled stock of large sizes varies considerably in diameter, these chucks at times give trouble. The above-mentioned differential-screw chuck locks itself in any position, thus allowing greater variation in the size of the stock than the others and therefore more nearly approaching the requirements of paragraph (*i*).

Stock Feed.—With regard to (*j*), the feeding forward of the stock quickly, yet without shock, is a matter of importance. For light stock, a cord and hanging weight are satisfactory; but when a weighty bar of metal is to be fed forward, the inertia of the bar is too great for such an arrangement to operate quickly yet without shock, so either a hand- or power-feed is necessary. Designs of hand-feed are shown in the illustration, Fig. 56. To manipulate heavy stock, power-operated mechanisms have been fitted by several firms to their machines (Figs. 57 and 58).

Fig. 54.—Chuck for 9-inch Flat-Turret Lathe (Ward).

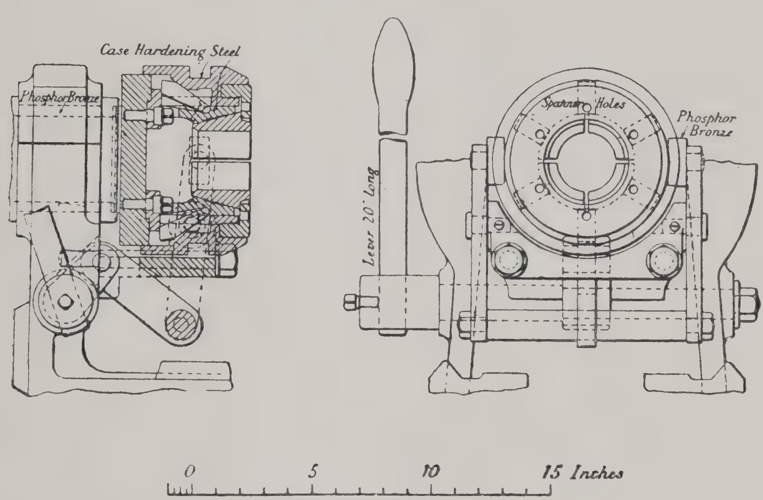


Fig. 57 shows two rollers, A A, pressed against the stock by springs. These rollers are rotated by worm-gearing at B B, and a right and left-handed worm and a helical gear C are on each side of the feed-box. Upon the back of the box, a loose ring D is fitted, having cut upon its side helical-gear teeth E. These teeth mesh with the helical-gears C upon the worm-spindles, and thus, if the ring

is held stationary while the gear-box rotates with the spindle, the worms will revolve and feed the stock forward. To arrest the rotation of ring D when required, a series of indentations are cut in its circumference, into which the ends of a trip lever F may fit. To facilitate the quick action of the feed, the trip lever is operated by a rod from the handle which works the chuck, thus, immediately the chuck is released, the feed gear is set in motion.

The above feed motion very closely resembles that first introduced by Messrs. Jones and Lamson, but that shown in Fig. 58 is different. It will be seen that rollers A A, with the worm-wheels B B, are carried in castings and swivel around the worm-spindles C C. These spindles protrude through the back of the feed-box, and have upon their protruding parts small spur-gears D, which mesh into an angular-gear E. This gear is keyed to the brake-wheel F, and that in turn rides loosely upon the boss of the gear-box. A strap surrounds the brake-wheel, and, by putting it in tension, the wheel is brought to rest, when, if the spindle is in motion carrying the gear-box with it, the rollers are caused to rotate.

Turrets.—With regard to paragraph (*k*) respecting the design of turrets, the author holds the opinion that the tendency in the construction of turret-lathes has been to place too narrow a limit upon the possibilities of the machines. This limit is occasioned by the type of turret and the consequent form of tools that have been necessary, the possible length of work being too short and the size of the cut too small.

The flat-turret lathe introduced by Messrs. Jones and Lamson in 1891, correctly known as the "Hartness" flat-turret lathe, was one that was in itself a distinct change and an improvement in turret lathes for producing long work. This machine is illustrated in Figs. 59, 60, 61 and 62. Fig. 59 is a sectional elevation of the head-stock, and Figs. 60, 61 and 62, show

Fig. 55.—Power-operated Chuck (Herbert).

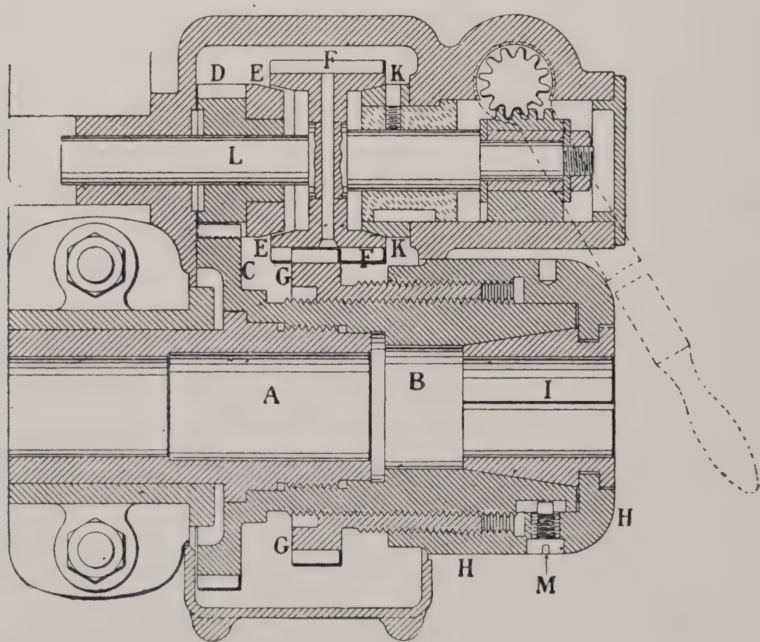


Fig. 56.—Stock Feed and Chuck Mechanism (Herbert).

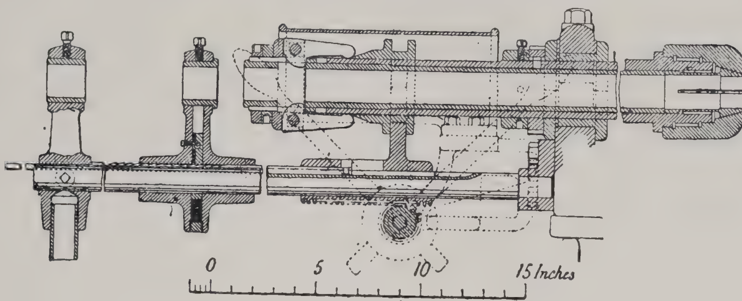


Fig. 57.—Roller Stock-Feed (Ward).

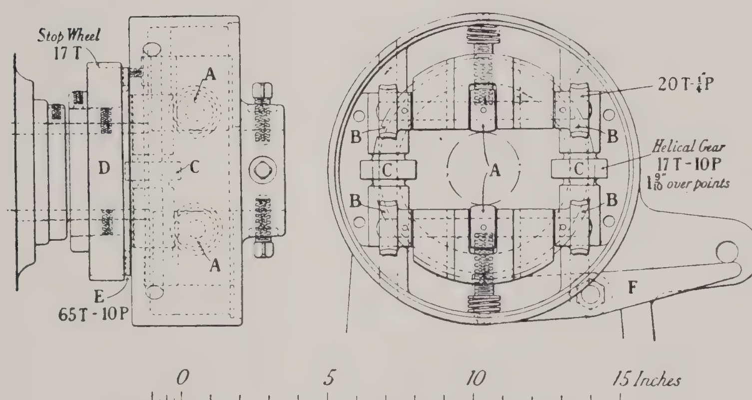
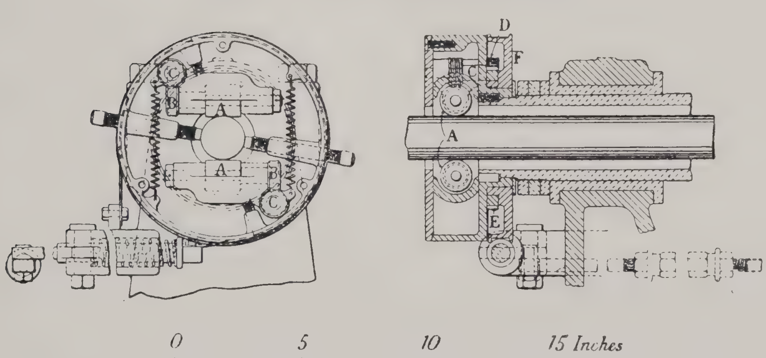


Fig. 58.—Roller Stock-Feed (Wolseley).



various details of the turret and its mechanism.

"*Hartness*" *Lathe.*—Upon examining Fig. 59 we see that there are several distinguishing features, the most important of which is the construction of the turret. A traversing carriage fits upon the bed, along which it may be traversed by hand or power. Upon the carriage there is fitted a low form of turret, which is little more than a flat plate. The details of this are clearly shown in the various views. It will be seen that the turret centres upon a pin

A (Fig. 61), connected with the carriage; but it is held in position by the gib-ring B B, that fits into a groove turned in the circumference of the turret. The locating bolt C is placed immediately below the tool position, and it is of substantial form, fitting into hard steel bushes.

For the purpose of withdrawing the locating bolt, a lever D is fulcrumed at

Fig 59 *Headstock*

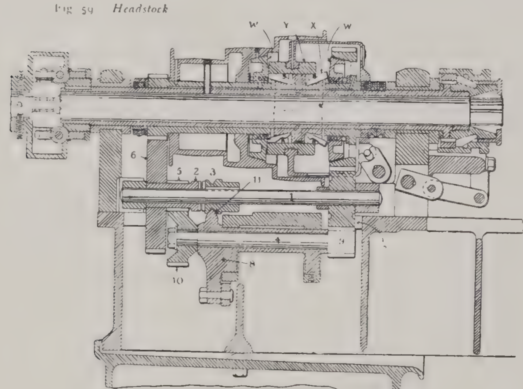


Fig 60 *Cross Section*

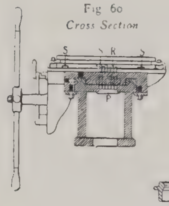


Fig 61 *Turret, Section*

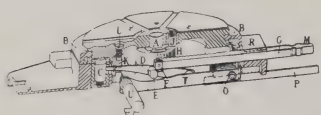
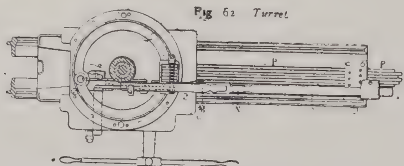


Fig 62 *Turret*



FLAT-TURRET LATHE ("HARTNESS," BY JONES AND LAMSON).

one end upon the carriage beneath the turret, and its other end enters a recess in the locating bolt. A spiral spring beneath the bolt continually pushes it upwards, so that, to release the turret for rotation, it is merely necessary to press down the lever D. For this purpose a circular pin E is attached to the side of D, and this is engaged by a small trigger F, carried in the end of the bar G.

For the purpose of rotation, a ratchet-ring H encircles the central boss of the turret plate, and upon its circumference there is cut a limited number of teeth extending about one half of it. On the upper part of this ratchet ring the ratchet teeth are cut. Carried by the turret, in a suitable position for engaging with this ring, there is a spring-actuated bolt which serves as a pawl J. The side of the bar G is cut with teeth as a rack, so that when it is pressed forward and releases the locking bolt, it also rotates the ratchet ring and carries the turret with it. To arrest the turret in position to receive the locating bolt, a spring-supported catch K engages the end of a screw L protruding through the turret plate.

The end of the bar G at M is shaped to receive a pair of spring clips N (Fig. 62) secured to an adjustable stop-rod O, and the object of this arrangement is to regulate the position at which the turret shall be caused to rotate. Thus, when traversing the turret away from the headstock, the bar G comes in contact with the stop-rod O, the spring-catches N taking hold. A further movement first causes the bolt to be withdrawn and then the turret to be rotated. Now, upon reversing the movement of the carriage, the bar M tends to leave O, but the catches N offer sufficient resistance to pull back the bar G, returning the ratchet-ring to its original position.

The cutting traverse is effected by mechanism within the apron on the carriage front, power being obtained from a traverse-shaft. An independent traverse-stop is provided for each tool. See also Figs. 61 and 62. Six adjustable trip-bars are let into the top of the bed at P. Immediately above these bars and within the carriage are six triggers, fulcrumed upon a pin at Q. Each of these

triggers is armed with a piece of bent wire R standing upwards and coming into contact with the outer edge of the turret. Their lengths are so adjusted that normally, as they touch the turret, it holds the triggers out of contact with the bars P; but in certain places upon the turret flange slight depressions S (Fig. 60) are cut to receive the end of one of the wires R. In this way the particular trigger corresponding to either tool is allowed to come into action for the purpose of stopping the traverse. As the trigger engages the rod P, it causes the rod T to draw back the catch U, which, in turn, releases the traverse mechanism.

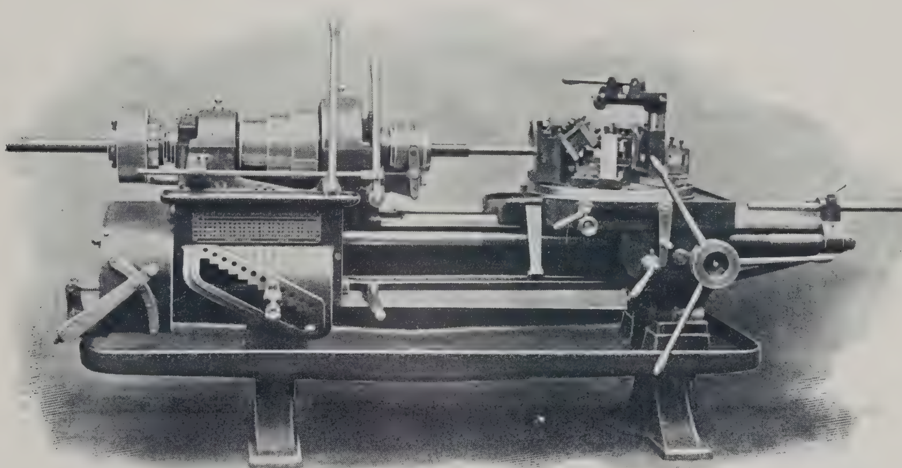


FIG. 63.—WARD'S 9-INCH FLAT TURRET LATHE.

Three speeds are obtainable at the mandrel without movement of the belt by two sets of back-gear, which, by ingenious arrangements, may be brought into action without stopping the machine. Friction-cones are placed within the cone-pulley and the driven gear at W W (Fig. 59), and they are brought into action by the toggle-links X over which the sleeve Y is caused to slide. There are two back shafts, 1 and 4, placed beneath the headstock. Upon the first, at one end, there is a loose sleeve 2 carrying two spur-wheels 5 and 6, and upon the other end, there is a single wheel 7 that gears with the one upon the mandrel. The shaft 4 has its bearings eccentrically placed within an oscillating sleeve 8, so that according to the position of the sleeve, the wheels 9 and 10 may either mesh with the corresponding wheels 5 and 7 or *vice versâ.* The oscillation of the sleeve at the same time actuates the clutch 3, for which purpose a segmental cam is placed upon the sleeve at 11. Thus the handle movement oscillating the sleeve puts the additional back shaft into or out of action, and, at the same time, couples up or breaks the connection by the aid of the claw-clutch 3 on the first shaft.

The chuck and stock-feed mechanism are both ingenious, and are similar to those shown in Fig. 54 and Fig. 57.

The lead given by Jones and Lamson has been followed directly by Ward, the latter design having some important improvements, the chief of which is the feed-change mechanism already described. The automatic traverse is by a lead-screw that may receive forty different speeds relative to the spindle.

For the sake of the working of the

automatic trip-gear, the connection of the saddle to the lead-screw is made by a half-nut A (Fig. 66) mounted within the saddle apron. Springs B B are provided, the continued tendency of which is to withdraw the half-nut away from the screw; but the movement causing it to mesh with the screw is obtained by a small crank C connected with a handle D at the apron-front. The stop-motion and trip-gear resemble the "Hartness" arrangement already described. The trip-lever E (Figs. 64 and 65) is moved by the stop-triggers F, which cause it to disengage a catch at G upon the spindle connected with the release-nut A. Thus, when the handle D is raised, the small crank C lifts the half-nut A engaging it with the lead-screw, and the trip-lever E engages

Fig. 64. *9-inch Flat-Turret Lathe, with Combination Change-Gear (Ward).*

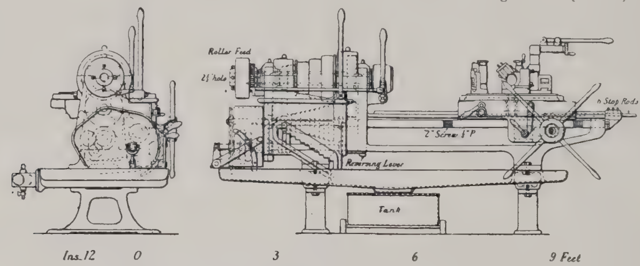


Fig. 65. *Details of Automatic Trip Gear of above Lathe.*

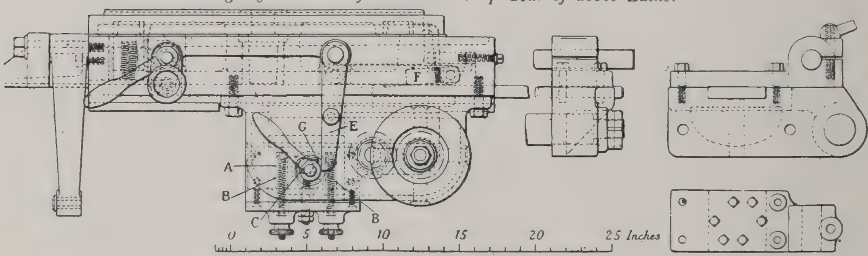
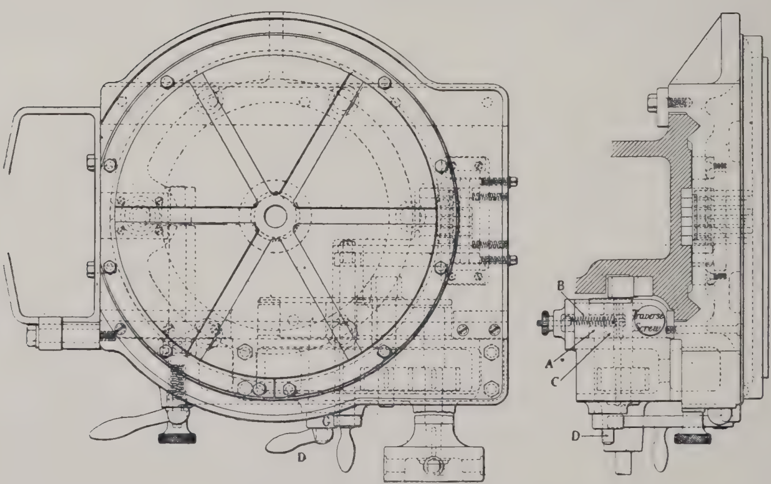


Fig. 66. *Details of 9-inch Flat-Turret (Ward).*



with the catch upon the spindle between the handle and crank holding the nut engaged and the springs in tension.

The Swedish Universal Turret Lathe has the turret rotating about a horizontal axis, which is mounted upon a cross slide. With this turret there are independent stops for each tool brought into position automatically by the same movement which rotates the turret.

containing the mechanism or automatic traverse.

A neat detail is the automatic trip-gear which stops the traverse for each tool independently at such place as is required. It consists of six bars A A laid in the bed, a piece being cut out near their ends at B, and mounted upon a cross rod C within the turret are six triggers D. Five of these triggers are always out of action, as only the one corresponding to the cutting tool is free to trip the traverse.

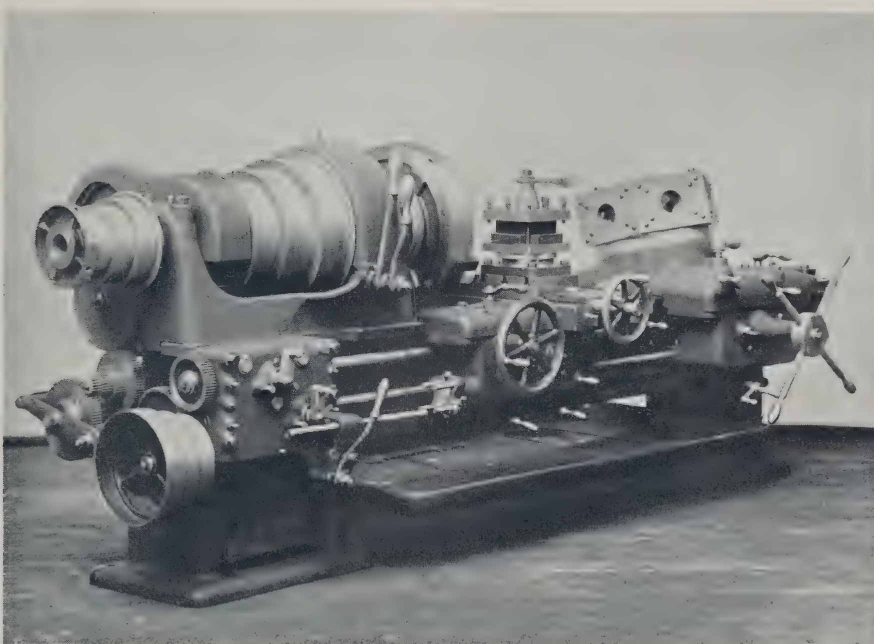


FIG. 67.—HEXAGON-TURRET LATHE (HERBERT, NO. 6).

Details of a Hollow Hexagonal-Turret Lathe are shown in Fig. 68. The turret is hexagonal that tool holders may be bolted upon the flats, the cutting tools coming close to the turret face, so that there may be little overhang. The bar being turned may pass through the hollow turret and the possible length is thereby increased. The turret is directly mounted upon a saddle which traverses along the lathe bed. The location bolt comes immediately below the flat of the turret carrying the tool in action. To the front of the saddle an apron is fitted

In the sectional elevation, a small rod E may be seen to be placed in a hole drilled through the saddle, its lower end resting upon the trigger. Its length is so adjusted that when the flat bottom of the turret is over the hole the small rod keeps the trigger out of action. Each trigger is provided with such a rod as this, and in the bottom of the turret suitably situated are shallow recesses F F, so that when one of them comes over a small rod E it leaves the

trigger free to engage with the catch B in the stop-rod. The automatic traversing motion is given to the saddle from a traverse rod by worm gearing. The worm is carried in a tumbler G which has an arm projecting upwards inside the apron at H, and upon its top there is a projecting piece I that engages with a catch J on the cross-rod C. It will be seen that upon either of the triggers

FIG. 68.—HOLLOW HEXAGONAL-TURRET (HERBERT, NO. 2A).

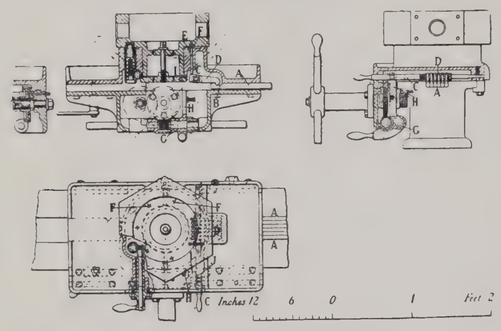
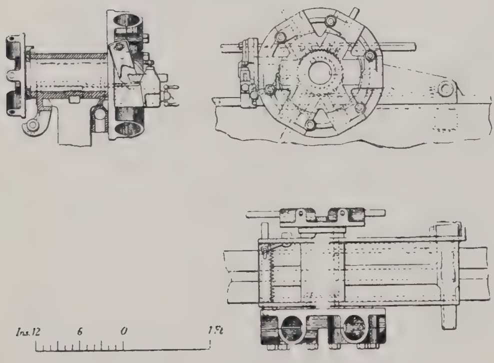


Fig. 69. Cross-Turret (Wolseley).



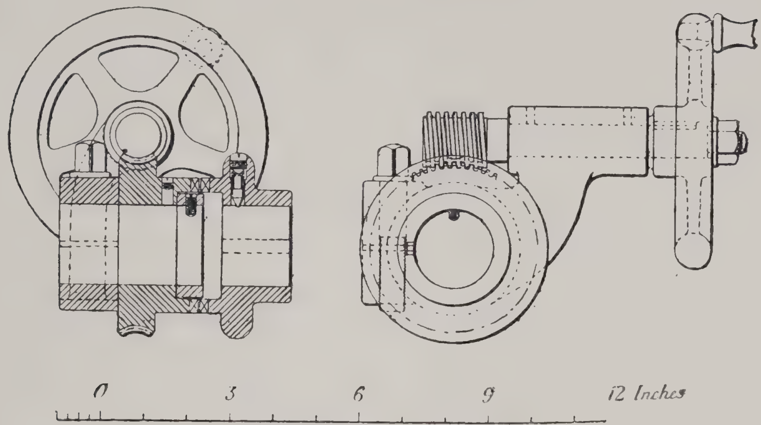
engaging a stop-rod the cross-rod C is arrested, releasing the projecting piece I, thus allowing the tumbler carrying the worm to drop out of action.

Details of the Cross-Turret Lathe, as shown in Fig. 69, have many novel points, the chief of which is the method of mounting the turret. The part of the lathe-bed supporting the turret saddle is set back out of the line of the spindle centre, so allowing all metal cuttings to fall clear of the ways. The stops are carried by a plate at the rear which rotates with the turret, to bring the stops into position as the corresponding tools come into action. The rotation is effected by a rack that drops into gear with a spur-wheel mounted upon the turret-spindle when the locking-gear is withdrawn. The worst feature about this turret is that the cutting pressure is wholly sustained by the locating pin.

Inclined-turret lathes have been designed for working upon large castings. Each of these are new tools, in which the details of design seem to comply with all of the requirements of turret lathes excepting paragraph (*o*), which does not apply to this type of machine.

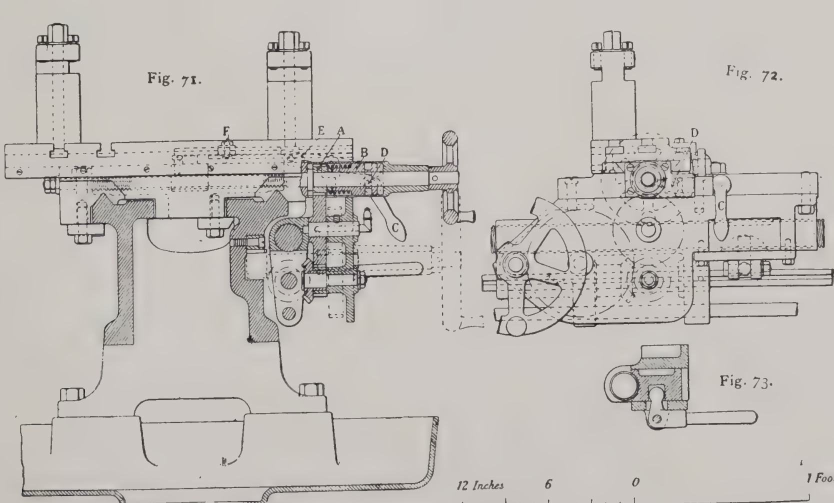
The work usually turned upon these machines often necessitates the use of long overhanging tools, such as boring bars, reamers, etc. The turret is therefore set over into an inclined position that these long tools may clear other parts of the machine. The one illustrated in Figs. 67 and 34 is a good example of the type. The headstock is provided with double friction back-gear, giving nine different speeds of spindle with one speed of counter-shaft. The chasing-screw receives its motion from the train of gears illustrated in Fig. 34, which may be combined with further change wheels to obtain the required number of threads per inch. There are two turrets, the main one, which is inclined and is carried upon a special saddle, is more especially intended to do the internal work upon castings, while the second turret, with four tool places, works upon the exterior of the casting. The automatic traverse for both these turrets is obtained from a splined-shaft which will be seen in Fig. 67, below the chasing-screw. In the mechanism for giving the traverse to the second turret, there are two tumblers, each with a pair of spur-wheels and a worm, swivelled about the splined-shaft, with handles protruding beneath the apron to the

Fig. 70.—Worm-Gearing for Turret Traverse (Herbert).



front. By lifting one of these handles, either the longitudinal or the cross automatic-traverse is put into action. When the automatic stops engage the stop-rod, the retaining trigger which holds the tumbler in place is released, allowing the tumbler to drop out of action. The mechanism for the inclined turret is similar in construction to that above mentioned. The trip-gear for this turret is similar to that described in Fig. 68. A three-speed-gear is shown in Fig. 35, by which the splined-shaft can be given three speeds for each position of the belt on the speed cone at the end of the spindle, thus nine speeds of tool traverse may be given.

Turret Traverse.—Paragraph (*m*) requires that provision should be made for both quick and steady motions. For light turrets a lever or a rack-and-pinion motion, with capstan handles, may be satisfactory; but when getting to heavier work some other means of traversing the turret must be introduced. For this purpose the worm-gearing in Fig. 70 is very useful when applied to heavier types of turrets that have hand traverse, as it enables a steady motion to be given. For still heavier machines, power-



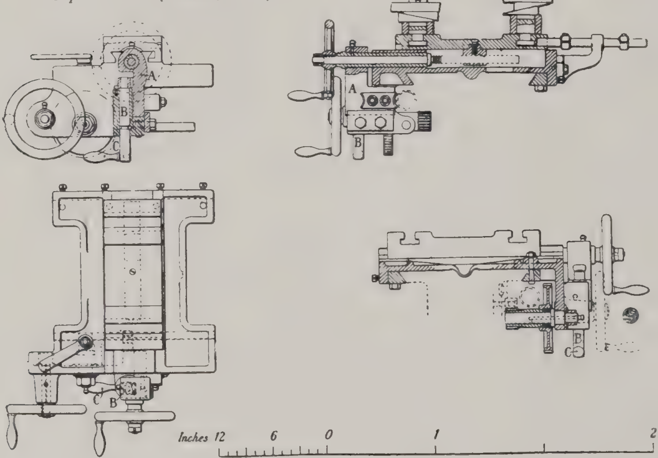
CHASING SADDLE. 9 IN. CAPSTAN LATHE (WARD).

operated traversing gear—such as those described—becomes a necessity, together with some form of automatic tripping-mechanism. It is rarely, however, that we find a quick-motion traversing-gear introduced for the purpose of changing the tool positions.

Cross Slide.—With regard to the requirements of paragraph (*n*), the cross slide referred to is of simple construction, suitable for the lighter types of turret lathes, in which all screwing may be done with dies, and the forming operations are simple.

When, however, the cross slide is intended to act as a chasing saddle, its construction must be modified and its length made greater. The chasing saddle illustrated in Figs. 71, 72, and 73 is fitted by Ward to their 9 in. capstan lathe. It will be seen to have a chasing-nut of simple form detailed in Fig. 73. There is an interesting trip-motion for automatically checking the power cross-traverse. A train of gears, shown in Fig. 71, terminates at the spur-gear A which rides loosely on the cross-traverse screw. A sleeve B is also fitted to the same screw, but a feather key prevents its rotation. The end of this sleeve is formed into a claw-clutch so that it may mesh with claws upon the side of the spur-wheel A, and there is a spring placed between the two tending to keep them separated. When it is required to put the cross-traverse into action, the handle C is raised; this, through the medium of a short spindle and crank D, causes the sleeve B to slide along and make the claw-clutch engage. To retain this in position, there is a lever E with a hooked end which catches into a notch upon an enlarged portion of the spindle D. To throw the cross-traverse out of action, an adjustable stop F engages the lever E, lifting the hooked end and allowing the spring to put the clutch out of gear.

Fig. 74. *Chasing Saddle. Capstan Lathe (Herbert, No. 5)*



The cross slide illustrated in Fig. 74 has a special device for simultaneously withdrawing the chaser and the half-nut. It will be observed that the half-nut is attached to a cast piece A, which, while stiffly attached to the saddle, is free to slide in a direction to and from the screw. A bracket upon its upper part embraces the cross-traverse screw. A small vertical spindle B has an excentric at its upper end and a handle C at its lower extremity. According to the way in which the handle is moved, the cast piece A may be caused to slide to or from the lathe bed, carrying with it both the half-nut and the cross-traverse screw. Thus the especial requirement of paragraph (*e*) is fulfilled.

Leader-Screws.—Paragraph (*o*) refers particularly to brass-working turret lathes for making such things as brass fittings, upon which much screwing has to be done. The practice in the past has largely been to provide a rocker-shaft at the back, with a chasing arm, the

traverse of which is derived from a short leader-screw on the tail-end of the spindle; but the threads so produced often vary considerably in size, owing to the spring of the arm.

Dies are often out of the question, on account of the weakness of the material worked; therefore, it seems to be the best practice to use a chasing saddle with leader-screw in a suitable position for a release-nut to mesh with it. By using different screws for the various pitches, the wear will be distributed over a number of screws; and, moreover, the screws being short, they are not very expensive to replace when worn. This is the practice of several firms making turret lathes for this class of work.

FULL AUTOMATIC SCREW MACHINES.

Headstocks.—With regard to (p), the stock-feed, as used on turret lathes, requires some degree of modification in its adaptation to the screw machine, and it usually takes the form of a tube with a spring nose-piece carrying the stock, and to which movement may be given by a cam motion. The variation in spindle speed should be such as will suit different kinds of material of all sizes within the machine capacity; but there is difficulty in getting a sufficient number of changes; consequently, as a rule, two speeds only are introduced, one suitable for turning at the larger sizes, and the other for screwing with a die. It is thus evident that if the machine is put upon brass of a size smaller than its maximum, the economy is doubtful. A discussion of either of the paragraphs (q)(r)(s) is scarcely possible without touching upon matters affecting the others.

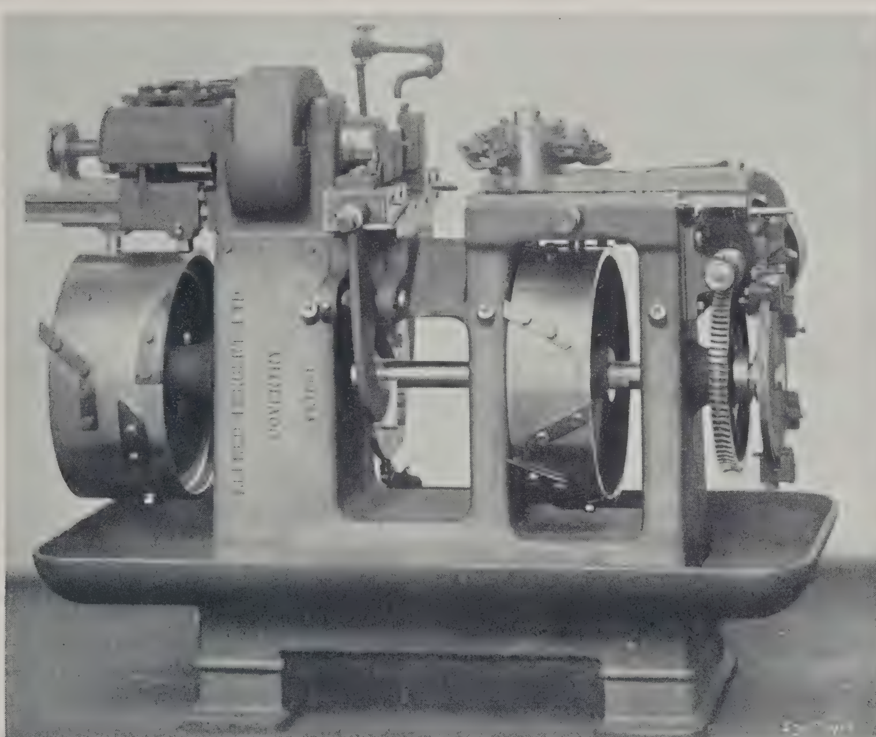


FIG. 75.—AUTOMATIC SCREW MACHINE (HERBERT).

(To be concluded in the August Number.)

THE PLACE OF SCIENCE IN EDUCATION.

By Dr. HENRY T. BOVEY, Pres. Canadian Society of Civil Engineers.

(*Concluded from page* 200.)

IF it be asked, what moral qualities are certainly cultivated by scientific work, the first that would be mentioned by most people is the love of truth. Now, while it is, of course, a fact that there may be a power of seeing truth without any corresponding love for it—which is the real moral quality—still, it must also be admitted that there are many people who think they have a love of truth, while in reality for want of the power of discernment, which science helps to teach, they may live a long life of self-deception, and swell the ranks of what we may call the "conscientious swindlers," who have been the bane of the Church and of Society. I may cite, as a practical illustration of the effect of scientific teaching, the testimony given to myself, by a teacher of an industrial class in New York, whose pupils were taken from the untrained class—that the boys try to deceive at first, but soon give it up when they find that their statements have to square with their finished work, which speaks for itself.

Neither does the benefit end here. The vision of truth, gradually unfolded before the inquiring spirit, tends to produce humility and reverence, especially in great minds; as witness the often quoted words of Sir Isaac Newton about the grand ocean of truth lying undiscovered, while he was like a boy playing on the shore. "Whatever service I have done the public," he says, "is not owing to any extraordinary sagacity, but solely to industry and patient thought." And these are the words of one, whose epitaph meets with universal consent for its conclusion, "let mortals rejoice that there has existed such and so great an ornament of the human race."

Nor has the humility led to want of effort, but the very contrary.

In such a man as Morse. for instance, when struggling against the apathy of an indifferent public; "it will be too late," said he to a friend who was comforting him with the hope of help to come soon—"I shall be dead then." He had had no food for twenty-four hours, but fortunately it was the darkness before the dawn. As in his troubles he had shown no bitterness, so in his successes he showed no pride, but an ever-deepening reverence, which found fit expression in the first telegram sent over this continent,—"What hath God wrought."

Some, or all, of these qualities, may, it is true, be natural and not trained. These men were geniuses, perhaps, but when we look round at the ranks of the men of science, and see how many of them have shown courage and endurance, accuracy and conscientiousness, reverence and love of truth, can we doubt that our complex nature is moulded by the very resistance with which it meets into a smoother outline, and pressed by the weight of difficulties into finer structure.

But while we claim all these advantages, and many more, for a truly scientific education, may not those who still look upon science as a poacher in the preserves of the ancient classics, an unwelcome intruder into the regions of literature and of philosophy, may they not, I say, claim with equal justice, that, as this scientific method may be applied to all these studies, it must bring in its train most of the advantages I have enumerated as being the handmaidens of that stately damsel—science? Perhaps, they may even add, that the scientific method, joined to the great intrinsic value of history and philosophy as educators, will gain instead of losing by its transfer to other soil.

Well, grant that in history we learn the relation of cause and effect by the bitter experience of a French Revolution,—a reaction from grinding tyranny—grant that we can gain a sense of proportion from a comparison of the results of the different forces which have moved nations, also that our power of judging is brought into continual exercise by the problems of policy, and by the moral issues which face us as we in imagination follow the lives and struggles of the makers of history. Let us allow that the relation in which we stand to our forefathers and their times is just as real and as important as is our relation to the past forests of the carboniferous age, without which we would find it necessary to emigrate to a more torrid zone. And certainly we must admit that, if we want to train our memories by the accumulation of facts, we will find ample scope in history, and, I may add, in geography.

Language, ancient and modern, will also supply us with much material for improving our memories. As it is sometimes taught, indeed, it amounts to little else, each new language supplying only another word to express the same idea. The scientific method being applied, however, we at once begin to observe that the word in the new language is not an exact equivalent, that it covers, as it were, a little more or a little less ground, and then enters in the necessity for the selection of an equivalent.

This necessity for a nice discrimination in the choice of words, either in our own language or another, is one of the greatest possible helps to that clearness of thought which is so invariable a sign of a truly educated mind as to be almost a synonym for education. For the true use of words, if carried as far as it would take us, would guide us through every region of human knowledge, and without right words, we must be lost in the unexplored lumber-rooms of our own brains.

Comparative philology will undoubtedly bring in many educative influences, which will reveal much of the life of other nations, and words themselves, in their histories, are often epitomes of the course of thought—records of increasing clearness of vision.

As Oliver Wendell Holmes says:—"Language is a solemn thing. It grows out of life, out of its agonies and ecstasies, its wants and its weariness. Every language is a temple, in which the soul of those who speak it is enshrined."

Classification and the reasoning powers will be needed in the proper study of the structure of the various languages. English, at least, offers a fine scope in this direction. A language in which, according to a modern grammar, an adverb is perhaps usually an adverb, but on occasion shown, can turn itself conveniently into an adjective or a preposition, should certainly turn out a nation of clear reasoners.

The manifest educational advantages of literature are so often confounded with those of language even by educators that it is no wonder if youth confuses them, and that the literature comes

in for its share in the dislike of the drudgery of language learning; no wonder that boys, who are popularly supposed to be learners in the school of taste, and embryo devotees at the shrines of noble thoughts, are really only learning to hate Horace and Æschylus for not having had the foresight to say what they had to say in plain English.

We cannot but see, however, that literature allows of the use of the scientific method in the department which is called criticism. That here there is room for observation, analysis, discrimination, comparison, judgment, and that, over and above this, that it extends our horizon, enabling us to read the thought and feel the emotions of men of other ages and other lands.

Philosophy, in one sense, has exactly the same aim as science, namely, the search for truth, but it does not cover exactly the same ground; both search for truth, but not for the whole of truth.

Science tries to find out the workings of the material universe, and philosophy, in the limited sense in which we usually employ it, *i.e.*, mental and moral philosophy,— in this limited sense, I say, it tries to find out the workings of the human mind.

In a great degree, also, both have the same method, so that actually the same words will describe the processes in both science and philosophy.

Thus, Sir W. Hamilton says, "In Bacon and Descartes our modern philosophy may be said to originate, inasmuch as they were the first who made the doctrine of method a principal object of consideration. They both proclaimed, that, for the attainment of scientific knowledge, it is necessary to observe with care,—that is to analyze; to reject every element as hypothetical, which this analysis does not spontaneously afford; to call in experiment in aid of observation; and to attempt no synthesis or generalization, until the relative analysis has been completely accomplished. They showed that previous philosophers had erred, not by rejecting either analysis or synthesis, but by hurrying on to synthetic induction from a limited or specious analytic observation. They propounded no new method of philosophy; they only expounded the conditions of the old. They showed that these conditions had rarely been fulfilled by philosophers in time past; and exhorted them to their fulfilment in time to come. They thus explained the petty progress of the past philosophy, and justly anticipated a gigantic advancement for the future. Such was their precept, but such unfortunately was not their example. There are no philosophers who merit so much in one respect; none, perhaps, who deserve less in the other."

Philosophy can scarcely be said to train the observing powers, for the term "observation" is usually limited to the training of the senses, especially the eye, to notice and distinguish material facts, but in a sense—and a very real sense—it does proceed from the observation of facts, for we can observe the characters and emotions of men singly or in groups, and observe them to some purpose. We read of Marlborough :—"The passions which stirred the men around him, whether noble or ignoble, were to him simply elements in an intellectual problem which had to be solved by patience." . . . "There was a touch of irony in the simple expedients by which he sometimes solved problems which had baffled cabinets. The touchy pride of the King of Prussia made him one of the most vexatious among the allies, but all difficulty with him ceased when Marlborough rose at a State banquet and handed him—a napkin."

Napolean's success, about which so much has been written, was also largely due to knowledge of men.

In philosophy, then, no less than in literature, we can discriminate and compare and judge; we can classify and finally generalise and try to arrive at an underlying principle from which again we can deduce theories, for instance, of government or of education. We can even test these theories by true experiments carried out in as scientific a manner as possible.

The conditions here are even more complex than in scientific experiments. It is much more difficult to determine what the facts are, very much more difficult to arrive at principles; so much so that one has said, "When from the phenomena of life we pass to those of mind, we enter a region still more profoundly mysterious. . . . Science can be expected to do but little to aid us here, since the instrument of research is itself the object of investigation. It can but enlighten us as to the depth of our ignorance, and lead us to look to a higher aid for that which most nearly concerns our well-being."

The scientific method, then, can actually be applied to history, language, literature and philosophy—and we will even go further than this and admit cheerfully that there are certain things which science should never be expected to teach to the ordinary mind—and things of so much value that it would be one-sided indeed to exclude them from any well-balanced scheme of education.

It is true that observation and imagination play a great part in science, yet years of study of ornithology would not have taught any one to see the relations between a lark and a poet, which made Shelley sing in addressing his skylark,

> "Like a poet hidden
> In the light of thought,
> Singing hymns unbidden,
> Till the world is wrought
> To sympathy with hopes and fears it heeded not."

It is true "that there is an infinite miracle in every tuft of grass," if we have only eyes to see it—it is true that science opens new vistas to the man who can feel the joy and peace of nature, who can draw inspiration from the wildness of its rugged hills, from the varied beauties of its flowering dales, from the ever-changing hues of the woods, from the rivers meandering through sunlit plains, from the constantly changing colours which play as it were on the face of the ocean, or from the loveliness of the June sky,—when

> ". . . Heaven tries the earth if it be in tune,
> And over it softly her warm ear lays."

It is true also that the telescope and the microscope have opened up to the student of science new worlds of marvellous interest and beauty, whose threshold we seem scarcely to have crossed, giving hints to the wise of what may be in the infinite beyond "the arras-folds that variegate the earth, God's antechamber," but we can hardly say that science actually trains the power of seeing beauty of form or colour—of perceiving the emotional force, as it were, of nature. This must come from a natural faculty, and according to the best part of the teaching of the new German philosophy, "the gladness that men feel when they are in touch with the overflowing and intoxicating power of nature" is itself an important source of energy. As Coleridge puts it,

> "Oh Lady! we receive but what we give,
> And in our life alone does nature live."

If this power of vision is to be cultivated it must be by means of some such studies as art, music, or poetry.

There is another direction in which it is desirable to get a clearer definition. The great good which arises from the power given by science of verifying every observation tends to make us exaggerate the service thus rendered, and to require that every kind of truth should be verified by the same kind of proof. To such an extent

is this carried that it causes some minds to refuse to accept any of the mysteries of the universe without absolute demonstration—hence, from lack of exercise, their faculty of seeing with the inner eye is in danger of atrophy.

Yet the fact that science will not teach faith is no proof that it is not a very real factor in the problem of life. And if it is—then it should be cultivated by other training—by opening our eyes to the relations of man to man, and of man to God, "if haply we may feel after Him and find Him," by acting on the principle which we wish to believe until we feel the ground under our feet, or as the French saying has it, "*En avant ! et la foi te viendra.*"

Now, admitting then, as I have done, that the scientific method with its attendant advantages can be, and already has been, in part, applied to many branches of learning, and admitting further that it will not teach everything, *I would yet claim for the application of the scientific method to the teaching of science itself that by it certain results can be obtained which can be obtained in no other way.* For example:—

(1) In the first place, that we find the scientific method applied in every branch of knowledge involves, I think, the tacit acknowledgment that it is the best known method of study. This being the case, it becomes of great importance that the method itself should be studied, and that—where it can best be learned—in man's laboratory and nature's workshop, for, in practice, if this is not done, it is very difficult to ensure that the method will ever be learned at all, or that there will be any reasonable chance of its being applied to the other studies. In how many classes are literature, history, and philosophy, and even science itself, merely crammed from books, and not studied in any proper sense at all!

(2) Again, one of the most characteristic features of the scientific method *when applied to science* is that it necessitates the careful training of the eye, the ear, and the hand—especially the hand—demanding a skill of manipulation, which tends to turn the man of thought into the man of action. We may rest assured that it does not mean nothing when we find the close association of great genius in works of the hand, with that wonderful practical capacity in other directions—in conquest, in laws and institutions, in government of men—which built up the Roman Empire. Experience has now shown that many minds are more easily approached and more readily developed by the systematic exercise of the sense of touch than in any other way. "Neither the naked hand nor the understanding left to itself can do much. The work is accomplished by instruments and helps, of which the need is not less for the understanding than for the hand." Perhaps no more striking proof of this fact can be given than the statistics of the various manual training schools, from which we learn that an increasing army of useful citizens has been—I would almost say—created out of that class from which so little had been hitherto expected.

(3) Thirdly, an advantage necessarily arising from the carrying out of the experiments required in so many departments of scientific work is the development of a keen and accurate perception of the truth by the constant checking of results. Our thoughts at every stage are crystallised into facts, and we are prevented from wandering into the often too hazy regions of hypothesis, and what is frequently miscalled pure thought—into the kind of thing which the Scotchman said was "no deep, but drumlie."

(4) Again, in experimental work, the cause and its results are brought into such close juxtaposition as to throw into the strongest possible relief the relation of cause and effect—the most fundamental in our searchings after truth.

(5) The scientific method also involves, of course, that constant and steady accumulation of facts, erroneously looked upon by many as synonymous with science, but which is more truly regarded as the material of science. We can never tell what fact will prove the starting point of some fresh discovery.

(6) Further, the learning of science fits a man directly to understand his environment, to cope with the every-day circumstances of his material surroundings, and therefore tends to develop in him common sense and practicality.

(7) It offers more scope for the free exercise of the powers, always very stimulating to interest in the student, and incidentally gives to the educator better opportunities for judging the particular bent of the character with which he has to deal.

"Because," says Plato, "no trace of slavery ought to mix with the studies of the freeborn man. For the constrained performance of bodily labours does, it is true, exert no evil influence upon the body; but, in the case of the mind, no study, pursued under compulsion, remains rooted in the memory. Hence, you must train children to their studies in a playful manner and without any air of constraint, with the further object of discerning more readily the natural bent of their respective characters."

(8) Finally, although it is hardly true, as is so often alleged, that the training in literature and language does not directly prepare a man for an immediately remunerative career—for what other preparation is considered necessary for the teacher, for the journalist, for the author, for the diplomat, or the politician?—still, it is more often the case that the teaching of science will prepare a man directly for his after-career, and for the prosaic but very necessary duty of as soon as possible earning his bread and butter.

Other points, such as the development of the faculty of resourcefulness, to which I have before referred, might no doubt be mentioned, but if we consider the very manifest advantages now given as essential to our well-being, *should it not be our duty to require that science should be taught to every one?*

Even after we have made up our minds how far science will and how far it will not help us in that development of the natural powers which is so large a part of education, we are still much hampered and hindered by circumstances which make it very difficult for us to carry out our ideals.

Speaking for many universities, we have a class of students entering them too young and too untrained to make an intelligent choice of subjects, and we have a large mass of opinion, both in and out of the university, in favour of the theory that in a country where young men must earn their own living at an early age, the training which they receive should all bear directly on their chosen profession, with a view to the saving of time.

This is a very natural if somewhat superficial idea, and the conflict of opinion becomes sometimes quite bitter between those who maintain it and those who believe that "the longest way round is sometimes the shortest way home," who believe the theory, formulated slowly through ages of comparative leisure, that the aim of teaching should be wholly, or in great part, educational, and that the purely practical should be added only at the very latest stage.

In the meantime, perhaps, one of the best compromises can be found in the further working out of the optional system.

The student might be allowed to choose his own subjects with even greater freedom than at present. His choice would, in all probability, be governed largely by the necessities of practical life—that is, he would choose

those studies which he thinks will most directly fit him for the career which seems open to him. In the teaching of these subjects, however, in any institution worthy the name of a university, the method to be pursued should be primarily, if not exclusively, educational.

To give a rough example of what I mean. Suppose a boy is to be trained for business. A thorough knowledge of book-keeping will, no doubt, be essential, but we can imagine that, in the end, foresight, accuracy, grasp of the large and the small, a thorough knowledge of men, might be of still greater importance, and that it would be better to sacrifice even some actual knowledge of useful details, rather than to teach without cultivating the faculties which would be ultimately necessary to any considerable success.

Now, as it happens, the study of engineering, which I have called the study of a combination of certain sciences, joined together with a view to their practical application, offers an easy opportunity for just such a compromise as we have found to be extremely desirable in itself. The subjects chosen for training may, nay, almost must, be those required in the after-practice of the profession, but at the university we need not aim at giving a thorough knowledge of all these, but rather at inculcating the power to deal with any set of circumstances, and to use the knowledge which books or experience have provided. As an actual fact, we have found that the success of our students often arises from this very power.

Besides the purely educational results, which I have tried to show are obtained from the study of science, there are certain other advantages to which I may just refer, and which are so considerable as to give to science an almost unrivalled claim on our attention. Such are the constantly increasing benefits which science, and especially engineering science, has conferred on all classes of society, in the great improvements in material condition; the practical overthrow of the barriers of time and space; and last, but not least, the great intellectual quickening, due to easier contact of mind with mind, which has come in the train of printing and photography, of steam and electricity.

Someone has said, "Every advance in intellectual education has been the effect of some considerable scientific discovery or group of discoveries." This is a subject which, at the entrance of another century, we are almost afraid to do more than suggest. Everyone is giving his views, and looking forward with a confidence born of pride in the achievements of the nineteenth century to certain conquests in the twentieth. Perhaps we would do well to remember that we are no longer *fin-de-siècle*, but only commencing a new conflict:

> "Down the roads we do not know,
> With our orders sealed we go."

As men of the twentieth century, we should not boast as we put on our armour, but rather see that we also are equipped with the patience and determination of a Darwin, the resourcefulness of a Stephenson, the reverent humility of a Faraday, for then, and then only, can we hope to win from nature those secrets which will enable us to enter upon our inheritance, and to find out yet unthought-of meanings of the first command to "subdue the earth."

Henry T Bovey

SOME ANCIENT AND MODERN TRACTION ENGINES.

By W. FLETCHER, M.I.Mech.E.,

Author of "Steam Locomotion on Common Roads," etc.

(Continued from page 209.)

II.—PRODUCTIONS OF LEADING FIRMS.

MESSRS. AVELING AND PORTER, LTD., ROCHESTER.

IT is our purpose to describe some of the productions of the leading traction engine makers, taking the names of the firms in alphabetical order. In the small amount of space at our disposal we can only glance at some of the old-time road engines, but we hope to pay more attention to the latest and best traction engines of the day. One of the firm's earliest self-moving engines is shown by Fig. 20. From the illustration it will be seen that an ordinary portable engine was provided with spur gearing from the crankshaft driving a chain pinion fixed on a stud, as per Fig. 21. A light pitch chain communicated motion to the main axle. The engine was steered by a horse in the shafts, or the "fifth wheel" arrangement could be brought into use, a seat being provided near the smokebox for the steersman. Fig. 22 illustrates the traction engine exhibited at the 1862 Exhibition. It was fitted with a steam-jacketed cylinder placed at the smokebox end of a flush-top boiler. Fig. 23 shows a section of the cylinder. The incoming steam was allowed to enter the jacket and pass round the cylinder to the stop valve at the top, as shown. The crankshaft was arranged at the firebox end; the driving gear was similar to the first engine, but a shorter chain was used. Cast-iron tyres were adopted in those days, and driving wheels made

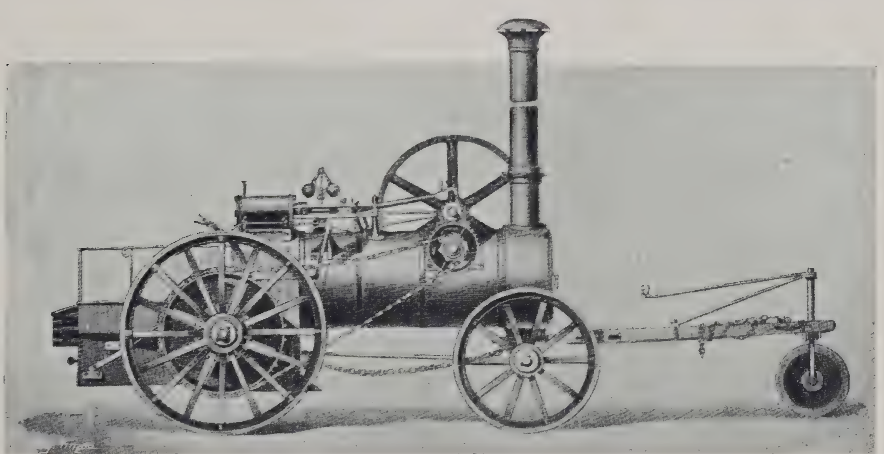


FIG. 20.—SELF-MOVING ENGINE.

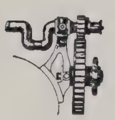


FIG. 21.—SPUR GEARING FOR CHAIN TRACTION ENGINES.

in this manner held their own for many years. The pilot steering gear was used. In some traction engines the driving and leading wheels had both spokes, boss, and tyres made entirely of cast-iron. Fig. 24 shows a longitudinal section of a traction engine boiler made by Messrs. Aveling and Porter in 1876. Figs. 25 and 26 represent other views of the boiler. Fig. 27 shows the cylinder base. The side-plates of the outer firebox were carried upward and backward for supporting the bearings of the crankshaft, countershafts, and axle on Messrs. Aveling and Porter's patented arrangement of 1871. The thickness of the plates, the riveted seams, the pitch of the stays, and general construction are so clearly shown that no description is required. Fig. 28 illustrates the first traction engine of the steam sapper type supplied to the War Department in 1868. Since that date the makers have supplied many traction engines for this department, improved in design as the years passed by. The engine shown was fitted with indiarubber tyres to the driving and leading wheels; the former were shod with steel shoes. The indiarubber tyres have had their day. They were expected by Mr. Thompson to revolutionise the road engines, and bring in an era of perfect transport on common roads; but the tyres were expensive—almost prohibitive, and they were found wanting in the clay soil of the Wolverhampton race-course in 1871, as we have shown. Leaving the

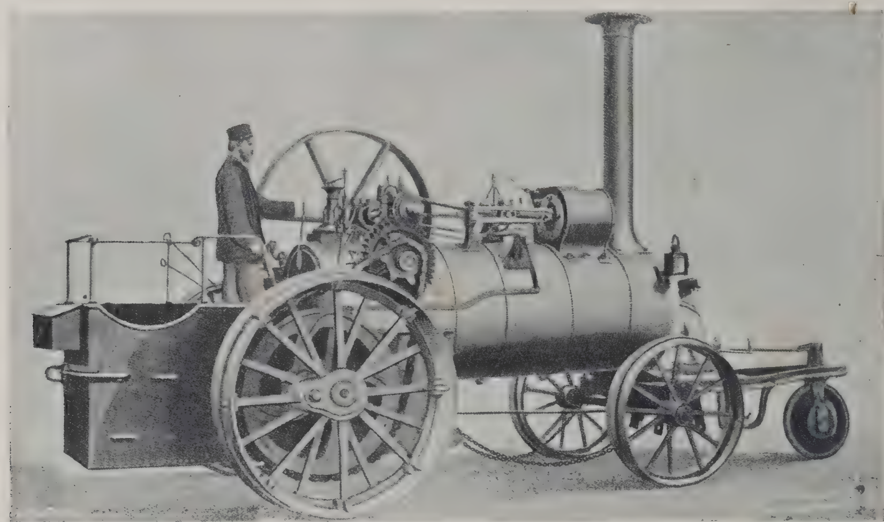


FIG. 22.—AVELING AND PORTER'S TRACTION ENGINE, 1862.

historical portion, we illustrate by Fig. 29 Messrs. Aveling's latest type of boiler for a compound road locomotive. The side-plates are bent outwards near the top; a width of about 6½ in. is thus gained. This extra width between the hornplates is rendered necessary in order that the gearing, two cranks, and four excentrics could be placed between the bearings. The outside steam chests of the cylinder cause more

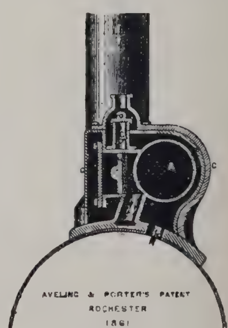


FIG. 23

Boiler pressure.	Weight on brake.	Circumference of brake, feet.	Revs. of crank per min.	Position of starting valve.	Average pressure, pounds per sq. in.		Indicated H.P.		Total indicated H.P.	Brake H.P.	Mechanical efficiency, per cent.	Governors.
					H.P.	L.P.	H P.	L.P.				
175	706	19·37	150	Full open	108·9	39·75	38·09	37·5	75 59	62·17	82	High-speed equilibrium

room to be required on the crankshaft, for when the slide valves are placed between the cylinders in the usual way, the four excentrics are keyed between the cranks; and when the steam chests are placed outside, the room on the crankshaft between the cranks is not available for the purpose. Fig. 30 represents the engine. One of this type was exhibited at the last Smithfield Show, having a "Worthington" feed-pump mounted on the fore-tank on the flywheel side; an injector is shown on the gearing side of the illustration. The engine is mounted on springs, and specially designed to meet the requirements of the military authorities; the wheels, gearing, axles and shafts are of exceptional strength. Fig. 31 represents diagrams taken from this engine, while the table gives some results of the trials on the brake at Rochester.

Messrs. Aveling and Porter's patented plan for mounting spur-geared road locomotives on springs is represented by the three illustrations. Fig. 32 is a transverse section of a traction engine. Fig. 33 is a section on line A. B.; Fig. 34 is a side elevation, with the right-hand driving wheel removed to show the driving disc. The third motion pinion is keyed on the second countershaft outside the hornplates. This pinion gears into the main spur wheel. The wheel revolves on a steel tube, the flange of which is firmly secured to the right-hand side hornplate. By this arrangement the main gearing is kept properly in pitch under all circumstances, and no motion of the axle can in any way affect its proper action. Between the main spur wheel and the driving disc there is fitted a steel plate, which is provided with two strong projections—these enter recesses in the spur wheel; while two more projections at right angles with the above enter the driving disc. This device transmits the power from the spur wheel to the driving disc, independently of the position of the axle. From Fig. 32 it will be seen that the driving disc is keyed to a long cannon, which forms the boss of the compensating gear centre, thereby passing the power from one side of the axle to the other. The right-hand side

FIG. 27.

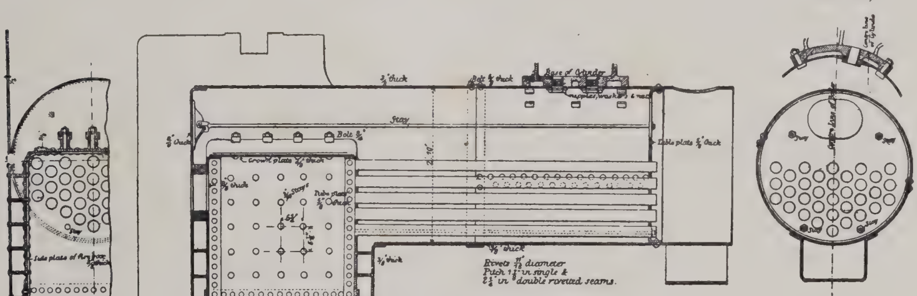


FIG. 25. FIG. 24. FIG. 26.

AVELING AND PORTER'S BOILER.

driving wheel and the right-hand side bevil wheel are both keyed to the main axle; the left-hand side bevil wheel is bolted to the boss of the left-hand side driving wheel, and thereby securing the proper action of the compensating apparatus. The main axle brackets are provided with slides, as shown in Fig. 33, secured to the inside of the hornplates; the bearings are coupled to the square steel spiral springs by links, as shown. The springs on either side work independently the one of the other, and therefore come into action at whatever position the road wheels may be in. The full weight of the hind part of the engine rests evenly on the springs in the usual manner. An angle iron frame is fitted between the hornplates above the axle bearings, and a stiff plate fits in between the hornplates beneath the axle slides.

Messrs. Aveling and Porter's road locomotive crane engine is represented by Fig. 35; the winding barrel is carried by two plate-iron brackets, as shown. A wire rope is used instead of the usual chain, the worm and wheel are carefully cased in to prevent the access of dirt, while the lubrication has doubtless been attended to. Motion is given to the worm shaft by bevil wheels from the crankshaft.

One of the firm's road rollers, fitted with Morrison's patent scarifier, was illustrated in the Engineering Times, Vol. II., as exhibited at the Royal Show at Maidstone, 1899. All the road rollers are fitted with the patent spring scrapers to the driving wheels as represented by Figs. 36, 37, and 38. The first illustration shows the application of the scrapers to the hind roller. Fig. 37 shows a section of the spring box, and Fig. 38 a plan of the arrangement. In Messrs. Aveling and Porter's compound agricultural locomotive, the slide valves are placed between the cylinders, and above the horizontal centre line of the engine. The valve rods are inclined to point to

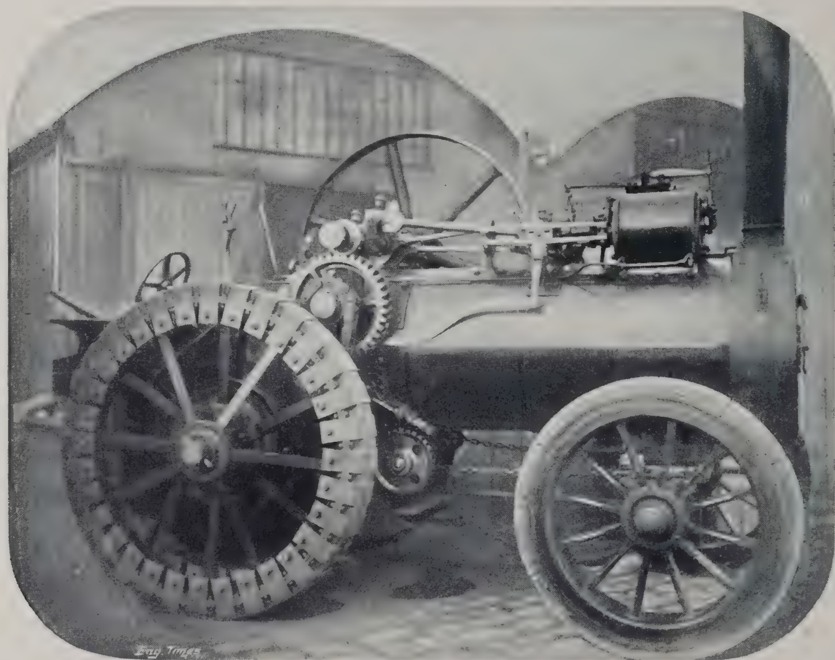


FIG. 28.—STEAM SAPPER, BY AVELING AND PORTER, ROCHESTER.

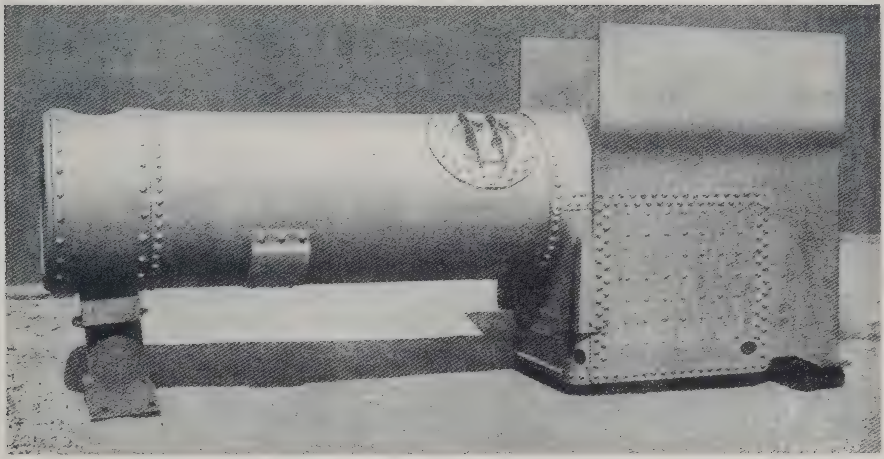


FIG. 29.—AVELING AND PORTER'S BOILER.

the centre of the crankshaft; most of the gearing is placed between the horn-plates; an outside pump is provided, and bored guides are used in preference to the ordinary guide bars.

MESSRS. CHARLES BURRELL AND SONS, LTD., THETFORD.

Messrs. Chas. Burrell and Sons were very early in the field with the celebrated "Boydell" traction engines. In 1857, and for several years afterwards, they made a number of powerful road engines fitted with the "Boydell" wheels for drawing ploughs on the direct traction system and for hauling heavy loads on the road. Fig. 39 gives a very faithful representation of one of these heavy hauling engines. In some cases the leading wheels were fitted with the endless railway system as well as the driving wheels. Fig. 40 shows an engine equipped in

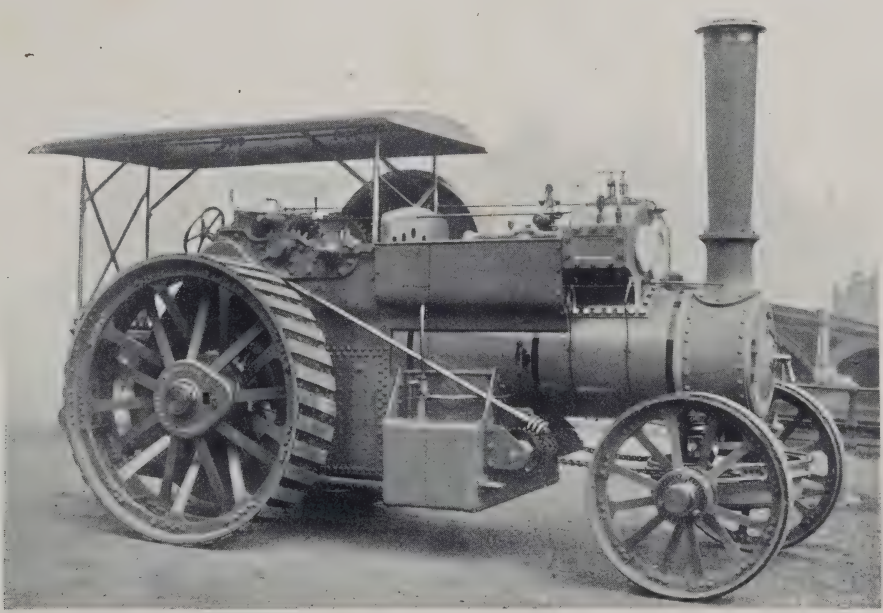


FIG. 30.—AVELING AND PORTER'S ROAD LOCOMOTIVE.

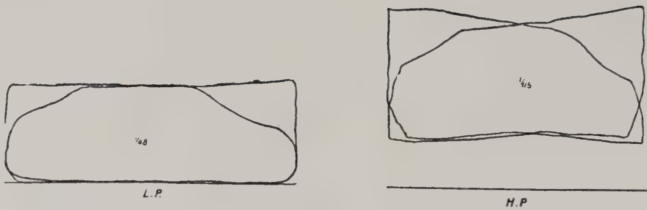


FIG. 31.

fitted with the "Boydell" driving wheels were steered by a horse in the shafts, like Fig. 44. It is said that horses never took fright when they met puffing and noisy traction engines upon seeing one of their own fraternity harnessed in the shafts. "It was very amusing to see a strange horse in the shafts. The horse would probably refuse to start at the right moment, with the result that he would gradually be pushed forward until he assumed a sitting position like a dog, and then he slid along until he realised that such a position was not a comfortable means of progression, when he

this manner. A water-tank was provided beneath the boiler barrel, and an outside pump fed the boiler from the tank. As it may be of some interest, we illustrate an early form of the "Boydell" wheel by Figs. 41, 42, and 43. A side elevation of the wheel is shown by Fig. 41. The shoes revolved with the wheel, and the wheel revolved upon the shoes; each shoe was taken up by the wheel as soon as it had passed over it.

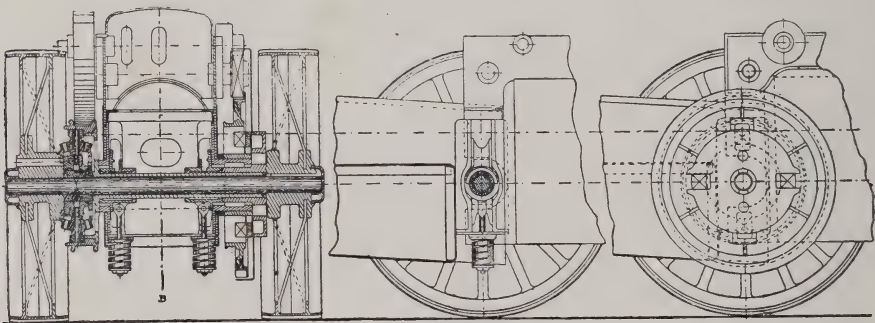


FIG. 32.—TRANSVERSE SECTION. FIG. 33.—SECTION OF LINE A—B. FIG. 34.—SIDE ELEVATION WITH RIGHT-HAND DRIVING WHEEL REMOVED.

SPRING MOUNTED TRACTION ENGINE, BY MESSRS. AVELING AND PORTER.

The shoes acted independently of each other, and changed their position at the top and the bottom of the wheel as just explained; the heel fell over by gravity soon after it passed the top of wheel; the heel was ready to receive the wheel, just as it had passed over the preceding shoe; the shoe at the bottom remained stationary whilst the wheel passed over it. The shoes thus formed a complete and continuous or endless railway. Fig. 42 gives a side view of one of the shoes, and Fig. 43 represents the plan of the shoe. Some of the smaller traction engines

would get up and commence to pull as hard as possible, and, of course, this having no effect on the engine behind him, this would last until it gradually dawned upon the animal that dragging was unnecessary, when all would go well. These traction engines were a certain cure for jibbing horses, and it generally cured them of other bad habits also." The "Boydell" traction engine was considered by the inventor "equally adapted to the wants of almost every known country, whether it is destined to travel over the sandy deserts of our

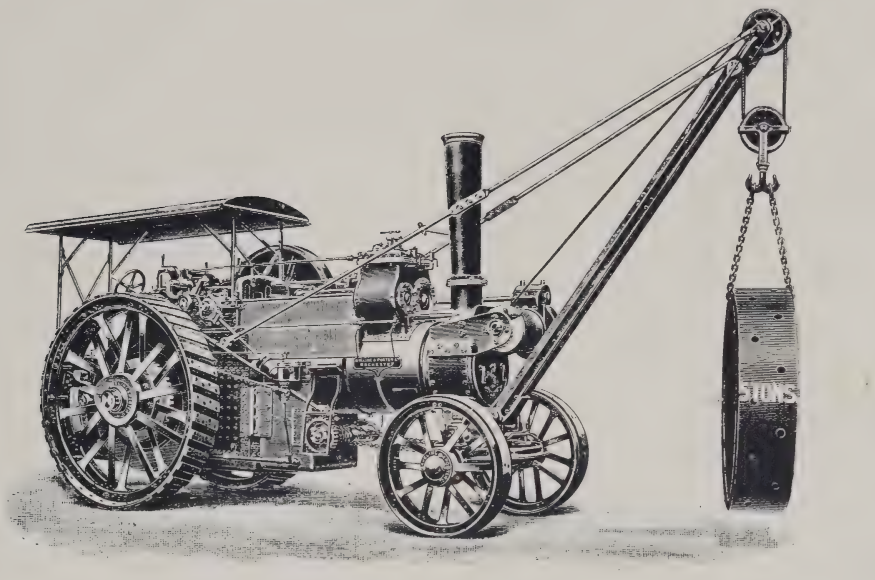


FIG. 35.—AVELING AND PORTER'S ROAD LOCOMOTIVE CRANE ENGINE.

Eastern possessions, over the muddy and almost impassable tracts of Australia, or over the snow-clad regions of North America, and the northern portions of Europe." Like many other inventions, its chief merit consisted in copying nature, and in fact it was neither more nor less than an imitation, in wood and iron, of a man's foot. The rails or shoes were six in number, and on each shoe was a piece of iron rail, exactly corresponding in length to the radius of the wheel; the shoe itself was rather more than one fourth longer. Thus, if the wheel were 4 ft. in diameter, the rail would be 2 ft. long, and the shoe altogether about 2 ft. 9 in. long. Of these extra 9 in., about two rather narrower than the centre piece projected at one end of the main part of the shoe, and answered to a man's heel; the other 6 in. at the opposite extremity were still narrower, though longer, and were therefore exactly the same as a man's toes. In

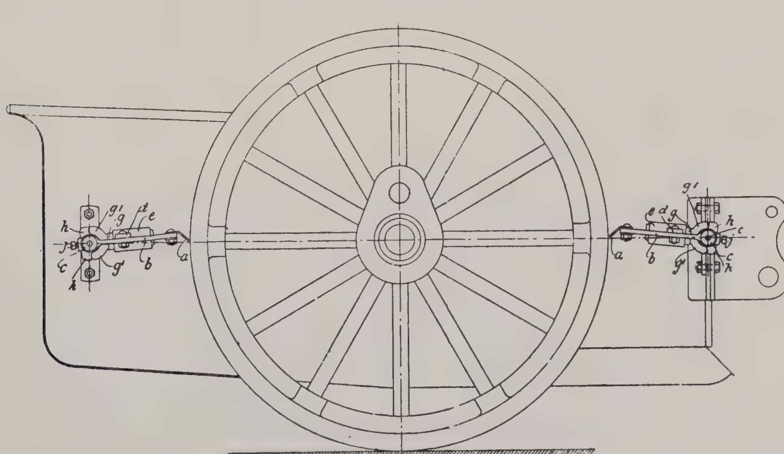


FIG 36.—AVELING'S SPRING SCRAPER.

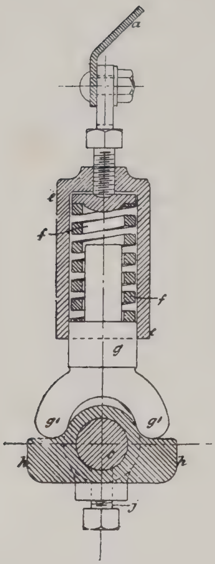


FIG. 37.—SECTION OF SPRING BOX.

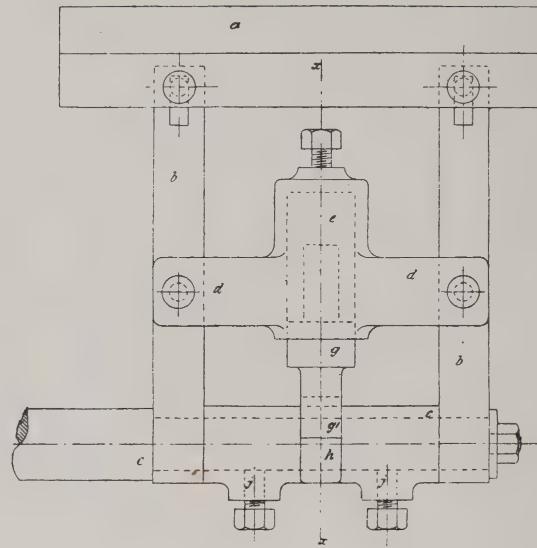


FIG. 38.—AVELING'S PATENT SPRING SCRAPER.

the centre of the shoe rose an arch of iron, which may be called the ankle, as the ankle worked on this in the same manner as a man, when walking, uses his ankle. The endless railway was not a success—the shoes knocked themselves to pieces; but many imitations have been patented having the same objects in view, none of which have survived to this time. Figs. 45 and 46 represent a side elevation and plan of a light chain traction engine, of which a very large number were constructed. The cylinder was placed at the firebox end of the boiler as shown; a pinion on the crankshaft geared into a wheel on the countershaft; two light chains were employed for transmitting the motion from the countershaft to chain rings, which were attached near the tyre of the

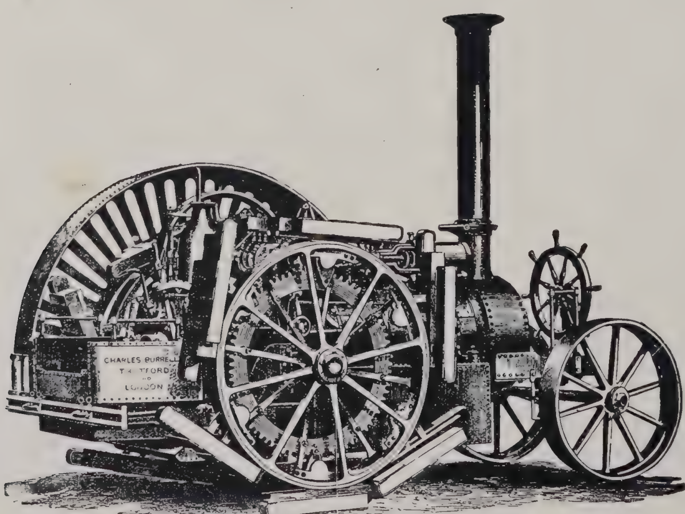


FIG. 39.—"BOYDELL" ROAD LOCOMOTIVE, MADE BY MESSRS. BURRELL AND SONS.

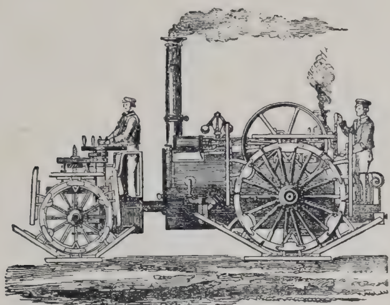
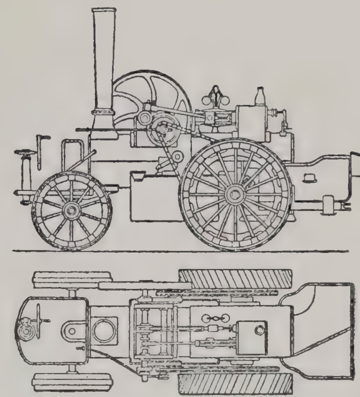
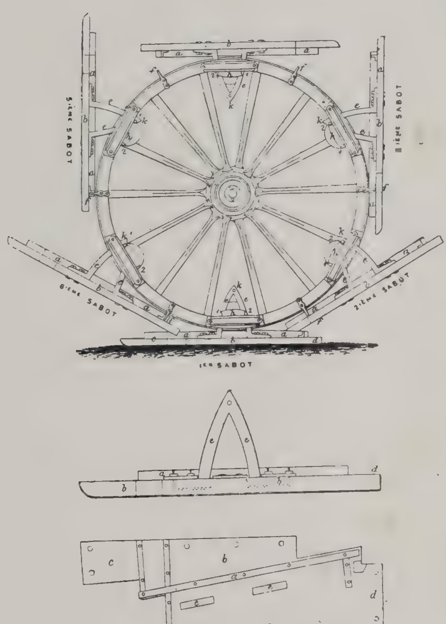


FIG. 40.—BOYDELL'S ENGINE.



FIGS. 45 & 46.—CHAIN TRACTION ENGINE.



FIGS. 41, 42 & 43.—BOYDELL'S DRIVING WHEEL WITH THE ENDLESS RAILWAY

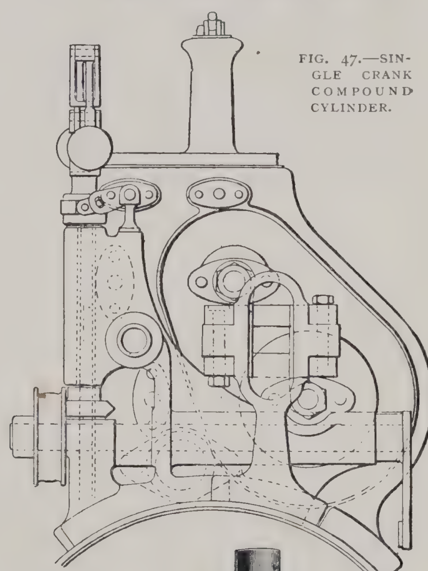


FIG. 47.—SINGLE CRANK COMPOUND CYLINDER.

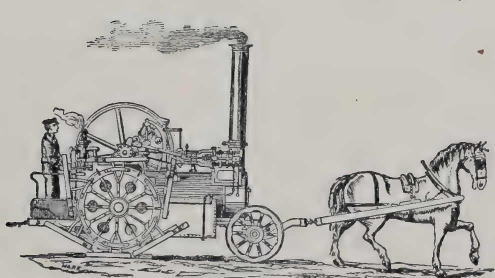


FIG. 44.—BOYDELL'S ENGINE WITH HORSE STEERING.

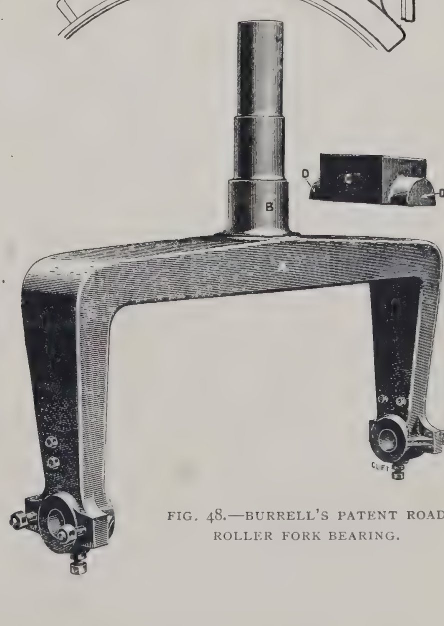


FIG. 48.—BURRELL'S PATENT ROAD ROLLER FORK BEARING.

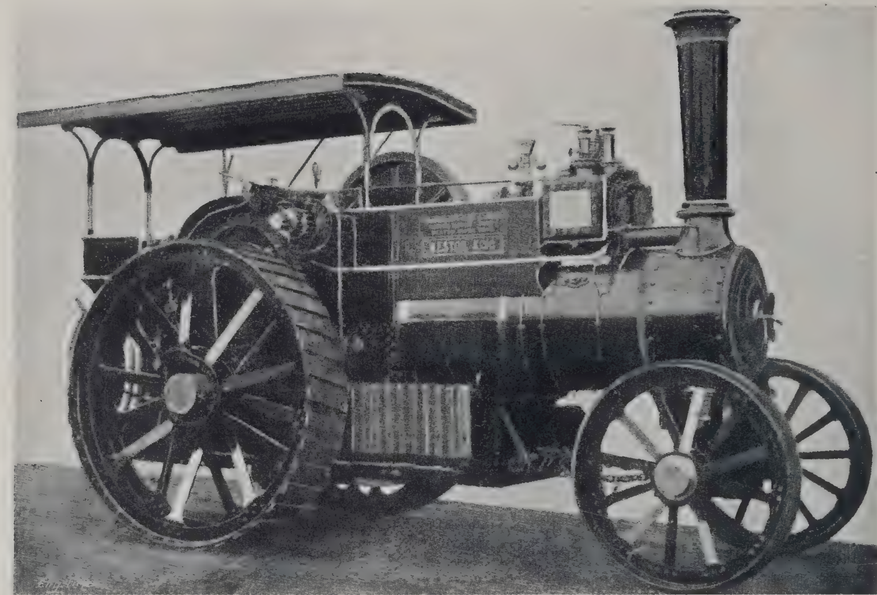


FIG. 49.—BURRELL'S TRACTION ENGINE—TYPICAL OF CLASS SENT TO SOUTH AFRICA.

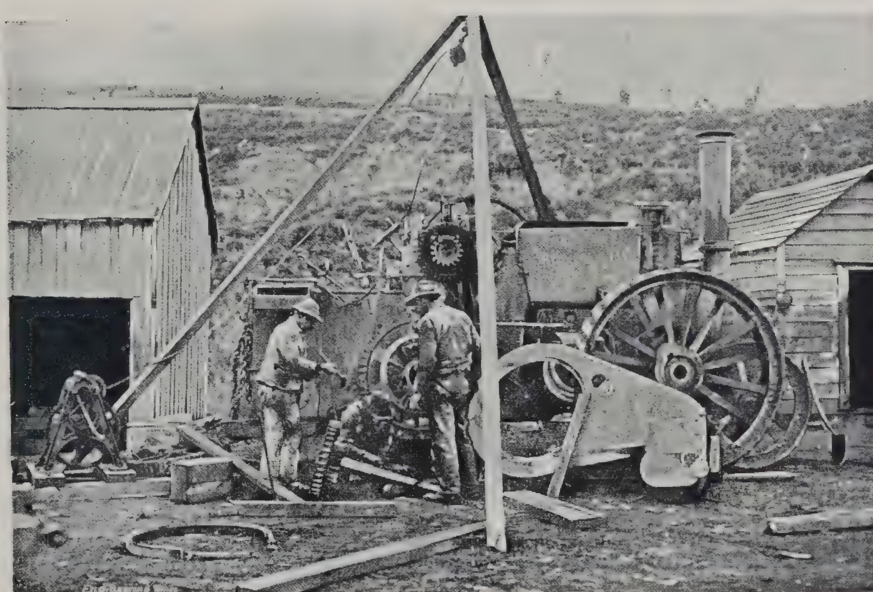
driving wheels. A fixed axle was used, mounted on a simple and efficient spring arrangement. The slack of the chains could be taken up, and tightening pulleys were also provided. A seat was fitted on a platform at the smokebox end for the steersman. One of the driving chain pinions could be thrown out of gear by means of a clutch actuated by a lever placed near the steersman's elbow. When a turn in the road occurred the clutch was thrown out of gear, and for the time being the engine was propelled by one chain. After the corner had been rounded the clutch was again thrown into gear. For fen land districts these engines were much sought after. Coming down to modern times, we may remark that Messrs. Burrell's patent spring-mounted arrangement has been illustrated in the writer's book on this subject.* Their patent single crank compound traction engine has had a long career. Fig. 47 shows the end view of the cylinder and motion brackets. The piston rods are coupled together to a very strong cross-head with long slide blocks. These rods actuate one connecting rod. The valve rods are connected together, so that one set of link motion reversing gear serves for actuating the two slide valves. Fig. 49 shows a road locomotive typical of the ones sent by Messrs. Burrell to South Africa. It will be seen that the single crank compound arrangement was not used in this instance, but the side by side compound cylinders actuated a double throw crankshaft. A fore-tank is arranged beneath the boiler barrel. The working parts are cased in, the fly-wheel is plated, an awning is erected over the driver. A bar is provided for carrying the wheel spuds as shown. Most of the traction engine makers have adopted two countershafts in their engines, which enable them to arrange the first motion gearing between the bearings within the box brackets. Messrs. Burrell and Sons use their patent clutch gear to pinions placed

* "Steam Locomotion on Common Roads." E. and F. N Spon, 125, Strand, London.

outside, but very snugly arranged to the crankshaft bearing. By their plan one countershaft only is used. Some makers claim advantages for inside gearing combined with two countershafts, others prefer outside gearing and the use of one countershaft. Messrs. Burrell's road-roller fork bearing may be referred to here. Fig. 48 shows the patented arrangement. In the illustration, A is the fork, and B the vertical stem. C is a square collar having half trunnions, D D, formed upon it. These half trunnions fit in recesses formed in the saddle casting which surrounds the fork stem, and allow the front rollers to rock freely in accommodating themselves to the inequalities in the surface of the road, without in any way reducing the bearing surface in contact with the fork stem B when the latter is canted. The portion of the fork stem B is free to turn in the collar bearing C, and the collar rocking upon the trunnions forms a good arrangement.

(*To be continued.*)

W. Fletcher.



REPAIRING A TRACTION ENGINE AT AN "UP-COUNTRY" STATION, NEW ZEALAND

THE PRODUCTION AND USE OF ACETYLENE GAS.

By W. DOMAN.

(*Continued from page* 240.)

II.—PROPERTIES OF ACETYLENE.

ACETYLENE, so named from its relationship to the radicle acetyle, and known during its earlier history as klumene, was first described in 1836 by Edmund Davy as a gas obtained by treating with water a residue frequently found in the production of potassium from cream of tartar and charcoal, and was called by him bicarburet of hydrogen.

It was not, however, until after 1892 that this gas was used outside the laboratory, its commercial production having been inaugurated by the enterprise of Willson, who appears to have been the first to produce calcium carbide in large quantities; and about 1895 the industry was introduced into Great Britain by the Acetylene Illuminating Co. starting the manufacture of carbide on a commercial scale.

Very little was known of acetylene until the researches of Berthelot in 1859, which made clear its true composition and method of formation. From this time our knowledge has steadily increased until it has become probably the best known of the hydro-carbon gases.

Pure acetylene is a gas of a faint ethereal odour, but as usually prepared it has a strong smell, due to a small proportion of phosphorous and sulphur compounds, which in the very slight traces present in the gas after the ordinary purification are sufficiently pungen to insure the immediate detection of any leakage.

For facility in reference, the figures relating to the composition and properties of acetylene are given in tabular form :—

Percentage composition by weight	Carbon 92·3 per cent. Hydrogen 7·7 ,,
Formula	C_2, H_2.
Molecular weight	26.
Density	13.
Specific gravity, calculated	·898.
Specific gravity, found	·9 to ·92
1 litre at O° C. and 760 mm. = 1·165 grammes.	
Heat of formation	47,700 calories.
Specific heat	1·26.
Heat of combustion	321,000 calories.
Temperature of combustion, calculated	11,180° C.
Freezing point	82° C.
Critical point	37° C.
Vapour tension at critical point	68 atmospheres.
Vapour tension at O° C.	21·53 ,,
1 volume liquid = 400 vols. gas.	

Acetylene is soluble in water to the extent of a little more than one volume, but in the ordinary generating apparatus this is found to give but little trouble, as, unless the bulk of the water is agitated with the gas, this proportion is only reached after a considerable time. When testing for quantity it is advisable to use a saturated solution of common salt, which can take up only about 5 per cent. of gas.

In acetone acetylene is remarkably

soluble, one volume of this liquid at ordinary temperature and pressure taking up 25 volumes; and at a pressure of 12 atmospheres, 300 volumes of the gas. Other liquids in which its solubility has been the subject of experiment are given in the following table:—

At Ordinary Temperature and Pressure.

1 *volume of*—		*Volumes.*
Water	dissolves	1
Carbon disulphide	,,	1
Petroleum	,,	1
Turpentine	,,	2
Amyl alcohol	,,	3·5
Stryolene	,,	3·5
Chloroform	,,	4
Benzine	,,	4
Acetic acid	,,	6
Alcohol	,,	6
Acetone	,,	25

Acetylene is endothermic; in other words, it splits up into its elements with evolution of heat. This takes place at a temperature of 780° C., and has been shown by Prof. Lewes to be the probable cause of the intense luminosity of the flame. The sudden evolution of heat due to the splitting up of the acetylene molecules alone creates a sufficiently high temperature to raise the carbon to a state of incandescence, and when there is added to this the heat of the burning gas, the temperature is sufficient to account for the very high degree of luminosity to which the carbon is brought in the flame.

This property of acetylene might be looked upon with suspicion in a gas used for illuminating purposes, were it not that the decomposition takes place slowly and gradually only in the region affected by the heat, and is not propagated through the whole bulk of the gas, nor does it take place with any explosive violence unless the gas is at a pressure of about 30 lb. to the square inch.

At this pressure acetylene becomes an explosive, and for this reason its use in liquid or compressed form has been forbidden by the authorities.

The changes undergone during the slow decomposition of the gas when brought about by heating it to a temperature of 400° C. and above are extremely interesting, though probably not of much practical importance.

The first action seems to be the condensation of the gas into benzine and other polymers, which split up with formation of ethylene, a number of hydrocarbons, including methane, and a small proportion of naphthalene with a thick, viscid tar, and finally, at a red heat, carbon and hydrogen.

It is this decomposition that presents the sole difficulty to be found in the commercial production of acetylene, owing to the heat evolved by the reactions of carbide and water.

When diluted with some inert gas, acetylene will withstand a higher temperature than other hydro-carbon gases, and it may also be compressed with safety when diluted with a sufficient proportion of an exothermic gas.

Other properties of the gas when mixed with air, doubtless due to its endothermic character, are its low ignition point, the greater violence of the explosion, and the wide range of mixtures with excess of acetylene that are explosive.

The temperature of ignition being as low as 480° C., a mixture of acetylene and air may be exploded by a glowing cigar end or a heated soldering-bit if the proportions are correct. This has also caused some suspicion as to its safety in use, which might have some foundation if the leakage from burners or from defective fittings were likely to be of the same extent as with coal-gas, or remain as long undiscovered.

The range of explosive mixtures of various gases and air are given in the following table, which shows the highest

and lowest percentage of the gas capable of being ignited :—

EXPLOSIVE MIXTURES OF AIR AND GAS.

Acetylene	3 per cent. to	82 per cent.
Hydrogen	5 ,,	72 ,,
Carbon monoxide ..	13 ,,	75 ,,
Ethylene	4 ,,	22 ,,
Methane	5 ,,	13 ,,

The minimum percentage given above for acetylene is considered by many experts as too low, and it is a fact that very weak mixtures are difficult to ignite, and the combustion is so feeble that they may in most circumstances be considered as comparatively harmless.

A peculiarity of acetylene is that in a confined space the most violent explosion is obtained, not with the mixture which is in the correct proportions for complete combustion, but with a mixture containing 50 per cent. of the gas.

The only obvious explanation of this is to be found in the explosive properties of acetylene when under pressure. In burning a 50 per cent. mixture in a tall glass cylinder, open at the top, the flame will be seen to travel slowly downwards to the bottom of the vessel. Presuming the action in a confined space to be of the same character, the combustion once started may be considered as proceeding with increasing rapidity as the pressure due to the heated products becomes greater, until the unconsumed portion of the gas reaches a pressure sufficient to cause detonation.

Owing to the low ignition temperature of acetylene and air, wire gauze will not stop the propagation of the flame. A "Davy" lamp would be quite as dangerous as a naked flame in an atmosphere of this gas, and tubes or orifices that are used with a coal gas "Bunsen" burner would be many times too large for acetylene under the same conditions.

Le Chatelier gives the following table of diameters of tubes through which the flame would be propagated with various proportions of the gas :—

Percentages of Gas.	Flame Propagated in Tube of Diameter—
From 2·9 to 64	1·57 in.
,, 3·1 ,, 62	1·18 ,,
,, 3·5 ,, 55	·79 ,,
,, 4·0 ,, 40	·24 ,,
,, 4·5 ,, 25	·16 ,,
,, 5·0 ,, 15	·08 ,,
,, 7·7 ,, 10	·03 ,,

In a tube of ·02 in. the flame is not propagated with any mixture.

The combustion of acetylene gives rise to a very high temperature, which has been calculated for a mixture of air and gas containing 7·74 per cent. of the latter as 2,420° C., and with a mixture of oxygen and 50 per cent. gas, 4,000° C., or 1,000° C. higher than that of the oxyhydrogen flame.

The actual ascertained temperature of the acetylene "Bunsen" flame is still open to controversy, and has been given by various observers as low as 1,900° C.; but it is, in any case, considerably higher than that of the coal-gas "Bunsen," which is to be expected both from its composition and endothermic character.

Acetylene forms an interesting series of compounds with copper, silver, and mercury, the majority of which are explosive, and de onate from a blow or on heating. The name generally given to these compounds is that of acetylides, but their constitution is but little understood, and a number of apparently differing compounds are generally included in this term.

The only one at all likely to be met with in the use of the gas is that of copper. This compound appears to be formed very slowly and in small quantities where acetylene containing ammonia or the usual phosphorous and sulphur impurities is allowed to remain in contact with the metal, provided that the conditions are favourable. Pieces of copper and various alloys carefully insulated from one another were exposed to the action of impure gas containing ammonia

for a period of nine months without showing any signs of the compound; but in another experiment where the metals were probably not insulated, and a much larger quantity of gas was brought into contact with them, two out of five strips were found with slight traces of acetylide.

When acetylene is brought into contact with a cuprous salt in a neutral or alkaline solution, copper acetylide is immediately formed as a reddish-brown precipitate, the exact composition of which is still uncertain, and is given by Berthelot as 2 $(C_2 Cu_2 H)O$; by Blochmann $C_2 H_2 Cu_2 O$; and by Keiser $Cu_2 C_2$. This precipitate is decomposed by hydrochloric acid with evolution of acetylene.

This reaction is one of the most delicate tests we have for acetylene, the merest trace giving in a solution of cuprous chloride containing ammonia the characteristic red precipitate.

An explosive compound is also formed from cupric salts, such as copper sulphate and nitrate, especially in the presence of metallic copper.

It is therefore very necessary in using copper salts for purifying purposes to make sure that the solution is acid, and remains acid while in use. In an acid solution the copper acetylide is not formed.

VIEW OF THE GIFFRE CARBIDE WORKS, WHICH SUPPLY A LARGE PORTION OF THE CARBIDE USED IN GREAT BRITAIN.

On storing acetylene for some time it was found to lose a portion of its illuminating value, and it has been also noticed that under the action of light a deposit was formed on the sides of the glass container. From whatever cause this action proceeds, it is not of any importance in the use of the gas for illuminating purposes, as the length of time required to bring about any appreciable change would never be allowed to lapse

in ordinary cases between the making and use of the gas. A rest of a day or even two days would improve instead of lowering its value, by permitting of the solution or deposition of some of the impurities present.

Acetylene is not poisonous in the usual acceptation of the term. Air containing 20 per cent. can be breathed for a considerable time without ill effect, and until about 40 per cent. is present, no danger need be feared by a healthy person. Recovery from the effect of a poisonous quantity is much easier than with coal-gas, which is far more dangerous in much smaller proportion.

COMPRESSED AND LIQUID ACETYLENE.

Owing to the explosive character of the dissociation caused by local heating or the detonation of a fulminate in compressed acetylene, it is too dangerous for ordinary use, and, in view of the many possible causes of explosion, such as a hasty compression with insufficient cooling, or a sudden opening of a valve leading to the reducing valve or other small chamber, it should be handled with great care under all circumstances.

Shock does not appear to cause explosion; but a spark, the detonation of a small quantity of copper acetylide, or heating due to a sudden check in expansion, are all possible accidents even in the laboratory.

With a view to overcoming this objection, the gas has been dissolved in acetone, and in this condition, at pressures below 56 lb. to the square inch, is free from the dangers of compressed acetylene; but the gas resting above the liquid is not. At higher pressures than the above the liquid also becomes liable to explosion.

Apparently there has been found a reasonably successful way out of the difficulty, by using in place of the liquid acetone a mass of kieselguhr or other absorbent entirely filling the cylinder, and saturated with acetone, which is then used to absorb the compressed gas. With this material the explosion does not appear to be propagated beyond the region affected by the heat or other exciting cause, and as there is no necessity to leave any space unfilled by the saturated kieselguhr, there appears to be but little danger, provided that the cylinder is not subjected to the action of heat over a large portion of its surface, or long continued. It has been suggested that this cause of danger may be also done away with by using a cylinder having seams or plugs of "fusible" metal, which would permit of the escape of the gas before any large portion of it were subjected to a temperature sufficient to cause dissociation.

Another method of compressing acetylene with safety is by mixing it with a good proportion of another gas, such as oil gas, which is being done by many of the Continental railways, and also by some of the English lines experimentally.

A mixture of 25 per cent. acetylene with coal or oil gas may be compressed to 200 lb. to the square inch, without exceeding the limits of safety.

III.—SAFETY OF ACETYLENE AS AN ILLUMINATING GAS.

One of the objections to the use of acetylene as an illuminant that was frequently raised in the early stages of the industry, and is still, perhaps, the most vigorous of the prejudices against which it has to fight, is that of its alleged danger of explosion.

The only foundations for this suspicion are, firstly, accidents which have happened while using the gas, and, secondly,

some of the properties due to its endothermic character.

Accidents which happen in the laboratory, and during experiments where the substance under examination is subjected to entirely unusual conditions, are to be expected with the most innocent of materials, and are not necessarily in the slightest degree an argument as to its danger. Leaving out all the accidents that come under the above heading, the remainder will be found due either to that old familiar source of accidents with coal-gas, viz., trying to find an escape with a light, or to some other circumstances that brought together acetylene, air, and a light, and which are more likely to lead to an accident with coal-gas than with acetylene, owing to the more powerful and unusual odour and the much smaller quantity in use in the case of the latter.

An explosion due solely to the faulty design of the generator is possible, but would display such an entire ignorance of the subject, or such a wanton and criminal neglect on the part of the manufacturer, that it is quite improbable. The only causes which one can imagine for an explosion of this kind would be—

(1) The existence of a pressure of gas capable of rupturing the container.

(2) The existence of a pressure of nearly 30 lb. to the square inch, together with a temperature of about 800° C.

(3) The presence of air in the carbide chamber, with a temperature sufficient to ignite the mixture of air and gas.

The only probable generator in which any of these conditions are at all likely to be found would be one in which there was no safety-valve or water-seal to the carbide chamber, and the outlet pipes were closed by cocks or liable to become choked up with a compact mass of lime or other substance, or one of the "dipping" or "displacement" type, in which the charge was uncovered, and a good proportion of air could be imprisoned in the same chamber.

The case against the gas itself, put in the strongest terms, is simply that—

(1) At a temperature of 800° C. it can split up into its elements with evolution of heat, and when under a pressure of about 30 lb. to the square inch with explosive violence.

(2) A mixture of acetylene and air in proper proportion will ignite at a temperature of 480° to 500° C., and therefore a lighted cigar may cause the ignition of an explosive mixture in the case of leakage.

(3) It is capable, under certain conditions, of forming with certain metals a compound that is explosive, and this may ignite a mixture of air and gas in some part of the generating apparatus.

Any idea of danger on the first count may be dismissed at once, seeing that at the highest pressures found in any generator the decomposition of the gas could only proceed slowly and harmlessly, as it is often found to do in a badly-designed apparatus that permits overheating. It would require a pressure of about one hundred times that ordinarily employed before the necessary conditions for an explosion could be obtained.

On the second count, which presupposes a considerable leakage of the gas, such as could only proceed from a broken or unplugged pipe, or from the generator itself, the danger would be so slightly increased by the low-ignition temperature that this cannot be considered as a valid objection.

Thirdly, although the compound formed by acetylene with copper is extremely explosive, the only damage one can conceive of as at all possible is that it might ignite a mixture of air and gas permitted to exist in some part of the apparatus. This compound is difficult to obtain even in the laboratory, and the conditions for its formation

are never likely to exist in any acetylene apparatus even if made of copper, which metal would be far too costly for any generator maker to use. The quantity formed would, in any case, be too minute to become a source of danger by itself.

The fact that the explosion of acetylene is sharper than that of coal-gas in similar quantity, and that the proportion of gas to air required for explosion is less, does not affect the case, seeing that the force of the explosion is proportionate to the extent of the leakage, and that with acetylene not only are leaks far less likely to occur in the house, but they would also be, as a general rule, much less in volume, probably one-third to one-fifteenth of that of coal-gas, according to the nature of the leak.

The danger from explosion of acetylene inside the house is of the same character as that arising from the use of ordinary gas, but is less in degree for the following reasons—

(1) The more penetrating and unusual odour, and the higher specific gravity of acetylene, would both lead to an earlier discovery of a leak.

(2) The most frequent form of leakage, that from an unlit jet, would be but one-sixth to one-fifteenth the amount of a similar leak of coal-gas.

(3) The piping is of smaller size, is more carefully put up owing to the penetrating character of acetylene, and is, therefore, far less liable to develope leaks.

Whatever danger there may be in the generator shed is due primarily to a defect in the apparatus, and secondly, to the presence of a light at an improper time.

Once the generator is started and the air cleared out of it, a bonfire might be lit underneath without causing an explosion.

Danger from this source is only to be looked for in—

(1) Bad design.

(2) Leakage of gas.

(3) Smoking, or the use of a light while charging or repairing the apparatus.

(4) Accumulation of gas from partially used charges, or from residue confined in a closed pit or receptacle.

The design of the various types of apparatus is dealt with in another chapter.

Leakage owing to flimsy construction should condemn the apparatus. There is no difficulty in making a generator as sound and permanently strong in all its parts as an ordinary water tank. Leakage from an open cock, or carelessness in closing any part of the apparatus, would be culpable negligence on the part of the attendant, but can hardly be provided against, though any danger from this cause may be greatly minimised by having the generator shed freely ventilated both at top and bottom, or entirely obviated, as regards any serious consequences, by leaving the whole of one side open.

Smoking or using a light when charging or cleaning the apparatus should lead to nothing more than singed hair or skin. Any generator likely to give rise to a serious explosion under these circumstances is imperfectly designed, and even if such a machine were put on the market, which is very improbable with our present knowledge of generator construction, it would doubtless be vetoed by the Home Office, who are now engaged in examining every form of apparatus offered to the public.

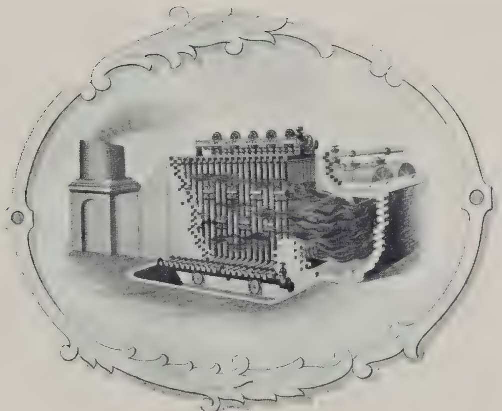
Repairs, or testing for soundness, should of course only be performed by a person who thoroughly understands the nature of combustible gases. The only instructions necessary to give an ordinary gas-fitter who has no experience of acetylene apparatus, would be that the gas being soluble in water may be given off from any water left in the generator, and that a heated "bit" is quite capable of exploding a mixture of acetylene and air.

Partially used charges or residues should not be allowed to remain in any

confined space. It is easy enough to find an open spot where lime may be thrown down, and if the residue is in the form of sludge an open-top barrel or pit can be used with perfect safety, or it may be run directly into the drains, if they are flushed down immediately after.

Taking into consideration everything that can be said against the use of acetylene, the only conclusion we can arrive at is that, used in the ordinary manner, it is not even as dangerous as ordinary coal-gas inside the house, and infinitely less dangerous than petroleum lamps. And in the generator shed, provided that the apparatus is properly designed and made, and the shed is partially open, so as to prevent any accumulation of gas through accident, there is no danger, except through gross carelessness while charging, repairing, or examining the apparatus with a light.

W. Doman



"CLAY CROSS" STANDARD ECONOMISER.

NEW MACHINERY, APPLIANCES, ETC.

(Manufacturers are invited to send particulars and illustrations of New Machinery for Notice, free of charge, under this Heading. Although the merits of every machine and appliance are investigated so far as possible by an expert, the Editor desires it to be understood that in some instances he is dependent to a large extent on the statements of manufacturers.)

THE "RACINE" HIGH-SPEED ENGINE.

WE illustrate (Fig. 1) a well-designed steam engine by the Racine Hardware Company, Racine, Wis., U.S.A., who confine themselves strictly to the manufacture of automatic engines of from 2 to 37 h.-p. inclusive. The field covered in the construction of this class of engine up to 40 h.-p. is entirely distinct from that of the larger sizes, and in order to secure the best possible results, the manufacturers have, for over twenty years, given the smaller sizes their undivided attention. The extended or "self-contained" base on their engines furnishes a rigid foundation for both engine and out-bearing, so that it is impossible for the out-bearing to get out of line.

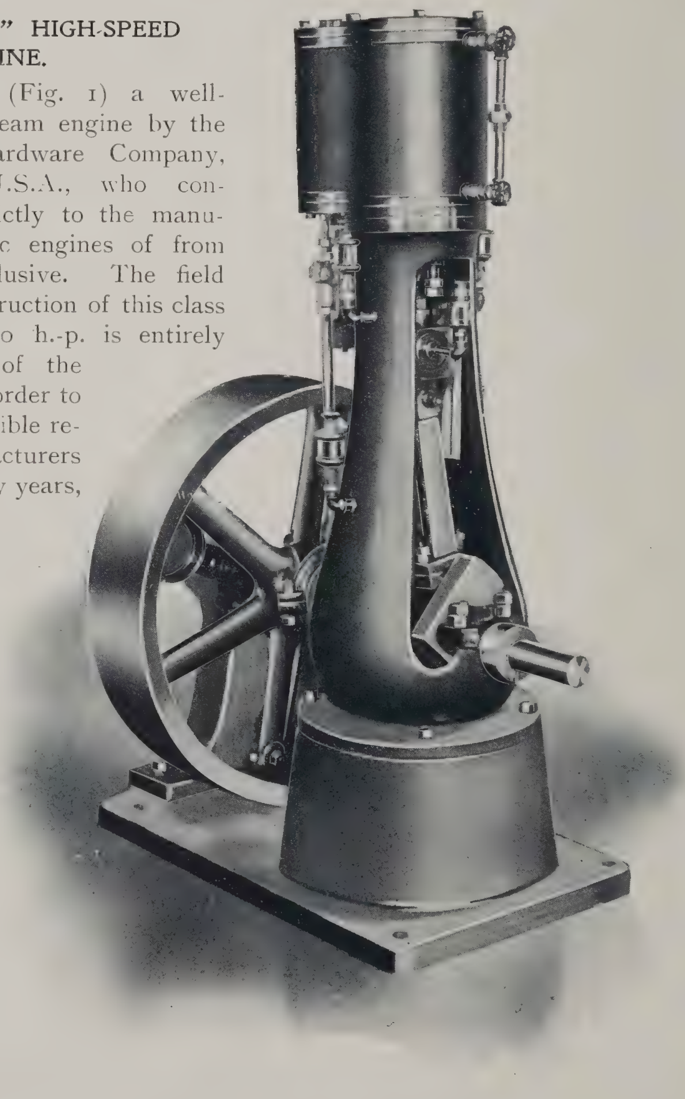


FIG. 1.—"RACINE" HIGH-SPEED ENGINE.

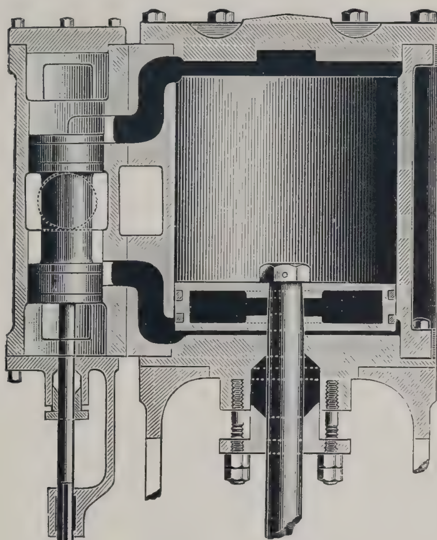


FIG. 2.—CYLINDER AND VALVE.

Every engine, including 2 h.-p., is furnished with an outbearing, which is secured to the extended base, giving additional support to the crank shaft. The frame is rigid and of tasteful design, adding to the pleasing appearance of the entire engine. The guides for the cross-head are machined out at the same time the frame is turned and faced, as also are the boxes for the crank shaft, thus insuring perfect alignment. The cylinder and steam chest (Fig. 2) are connected as closely together as possible, thus reducing the clearance space to a minimum. The valve is a piston valve, fitted with rings and well balanced. The valve is designed to cut off at one-quarter stroke, and at 85 lb. pressure will deliver the full power at which the engine is rated. All exposed parts of the cylinder and steam chest, except the top and bottom heads, are covered with asbestos cement. The cylinder and steam chest are jacketed with Russia iron.

The connecting rod, as shown here in the side and edge view (Fig. 3), is made from a solid steel forging. The crank boxes and bushing are made of a special mixture from a formula adopted by the United States navy, and used on all of their engines. The bushing is split and all wear taken up by means of a taper key. The crank end is of the marine type, which the manufacturers find the best suited for high speed work. The studs are steel and of ample size for the work. Each is fitted with a jam and lock nut, also a safety key, not shown in the illustration.

The bearing for the piston rod is one and one-half times the diameter of the rod. The cross-head shoes have large bearing surfaces, insuring long life and smooth, cool running qualities. Means are provided for taking up the wear. The cross-head pin is of steel, fitted to the cross-head with a taper fit on both ends. The pin is made hollow, with small holes drilled in the top surface, so that with the oil cup on the end of the

FIG. 3.—CONNECTING ROD.

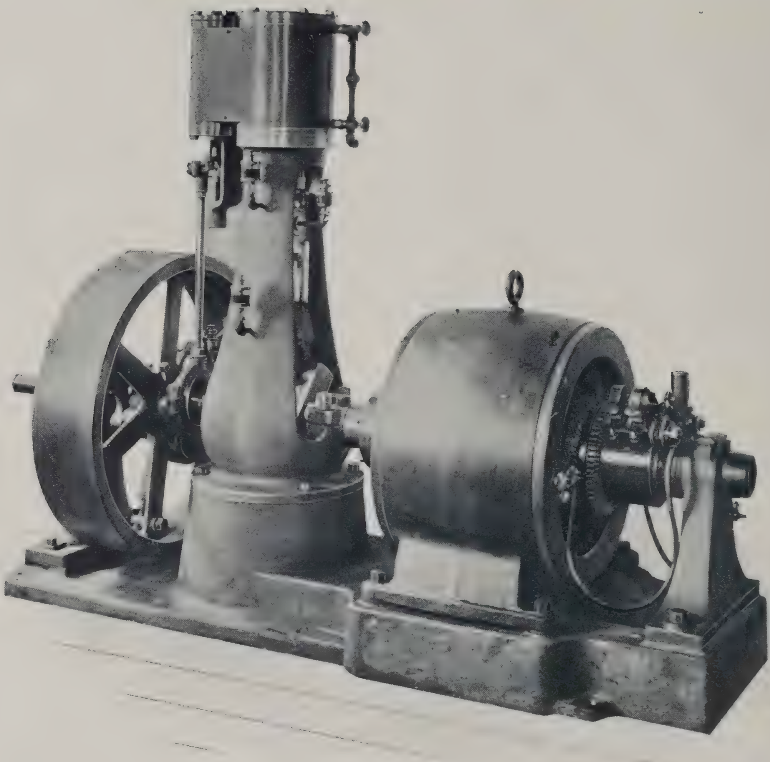


FIG. 4.—7 × 8 "RACINE" ENGINE DIRECT CONNECTED.

pin the pin and bushings are always kept well lubricated.

One of the most important features in an automatic engine is the governor, and this is particularly true when the engine is used largely for operating electrical apparatus or for other purposes requiring close regulation, uniform power, and extreme economy.

The governor controlling this engine is the "Rites Patent," which has already been described in these pages (Vol. I., No. 5). It is perfectly balanced and extremely simple in construction and operation.

The crank used is a centre crank, which is forged from a solid piece of steel. The crank pin is provided with an automatic oiler, which furnishes a liberal supply of oil, and permits of the engine making long runs without stopping. The shaft is supported by three bearings, one on each side of the crank and close to it, and another outside of the governor, beyond which the shaft extends far enough to attach an extra pulley. If desired, the shaft can be extended on the opposite side of the frame from the governor. A sight feed cylinder lubricator is used.

In Fig. 4 is shown a 7 × 8 "Racine" engine direct connected with dynamo for electric lighting purposes. All parts of this engine are made to standard gauges and jigs, and each and every part is made interchangeable, a feature that will be appreciated by users of power or machinery.

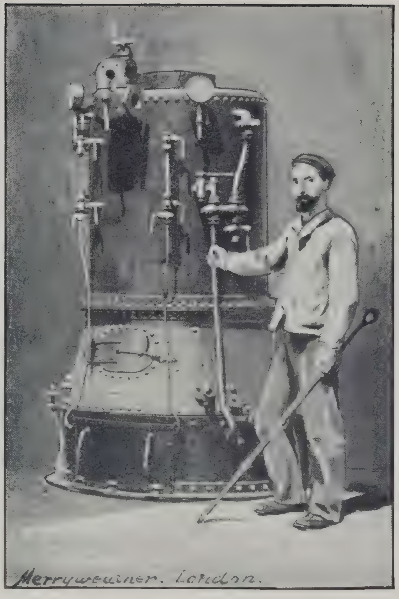
MERRYWEATHER'S WATER-TUBE BOILER.

WE give an illustration of a portable water-tube boiler, recently constructed by Messrs. Merryweather & Sons, Limited, for the Dover Harbour Board. The boiler has several special features, and on test showed remarkably good results. We are informed that it is about half the weight and occupies half the space of boilers previously used for this purpose.

Steam can be raised from cold water to a working pressure in from 20 to 25 minutes, instead of nearly an hour, as has previously been the case.

The whole shell of the boiler can easily be removed by taking out a few of the bolts, and the interior plates and tubes are then completely accessible, and can be cleaned without the necessity of a man entering the boiler. It also has prominent advantages with regard to safety and reliability.

The boiler constructed for the Dover Harbour Board is capable of supplying ample steam to an 8 in. centrifugal pump, having the power of raising 1,500 gallons of water per minute. Its weight is approximately 25 cwts., and it has been specially designed for use with salt water. The boiler was tested on a 12 hours' run at Dover, under the supervision of Captain Iron, salt water being used throughout the trial. During the whole of this period not the slightest sign of priming was visible, and a steam pressure of 100 lb. per sq. in., which was 25 per cent. more than the contract pressure, was easily maintained.



MERRYWEATHER'S PORTABLE WATER-TUBE BOILER.

At the conclusion of the 12 hours' run the boiler was opened up, in order to ascertain if sufficient deposit had accumulated to in any way impair its efficiency. It was, however, found that the amount of salt present was practically negligible; in fact, the boiler was at once closed up again, it being considered not necessary to clean it in any way. We believe this is almost the first time that a water-tube boiler has been constructed to use salt water, with the exception of some of the same type previously made by this firm, one of which was supplied to Admiral Gordon for use on his steam yacht, which gave great satisfaction.

ENGINEERING LITERATURE.

Land Surveying and Levelling.

By Arthur Thomas Walmisley, M.I.C.E., F.S.I., etc. London: D. Fourdrinier, *Builder* Office, Catherine Street, W.C. Also of Whittaker & Co., Paternoster Square, E.C. Price *7s. 6d.*

This work is one of the *Builder* series of text books for students, and after a careful perusal of the contents, we are inclined to think that it is the best treatise of the kind extant on the subjects of Land Surveying and Levelling. Efforts have been made by others to render accessible in a single volume what was formerly scattered through many books, but previous attempts in this direction have not been altogether successful, and it is a pleasure to meet with a text-book which contains within its covers practically everything that a student should know. We do not mean to imply that this book, good as it is, can take the place of practical instruction in the field from an experienced surveyor, but if used in the proper way to supplement outdoor lessons, it should prove of distinct service to the intending surveyor.

The book comprises twenty-two chapters, devoted in turn to the different branches of the work of a surveyor. Starting with instructions on ranging out a line, the student is gradually initiated into the mysteries of setting out perpendiculars, plotting angles and plans, computing scales and planimetres, taking levels, etc. Precautions in the handling of instruments are also given, although the limits of space allow their actual use to be only briefly described. The descriptions are, however, sufficient for the purpose, for, as the author points out, once the construction of an instrument is understood, and the general principles of its application become realised, a little outdoor practice will contribute more towards efficiency than several hours spent in reading written descriptions of field work.

Although in this country the Ordnance Survey has in some respects done away with the necessity of making surveys of any very great magnitude, no survey of any considerable extent can be conducted without the aid of trigonometrical principles, and the chapter on the use of trigonometry should be found of great value to the future professional surveyor, particularly if he be likely eventually to undertake work in the colonies.

We should not omit to mention that this text-book contains an exhaustive chapter upon Parliamentary surveying, in which full details are given upon the preparation of plans and sections for Parliament connected with projected schemes having reference to railways, tramways, docks, water and gas supply, electric lighting, and other works. This branch of surveying differs so much from ordinary chain or theodolite work that many qualified surveyors should find it of considerable service. This, and also the chapter on railway surveying, will no doubt be found useful by engineering students.

The author has included in the volume no less than 140 illustrations and diagrams, of a very complete and comprehensive character, which add considerably to the value of the work.

Field Work and Instruments.

By same author and publishers as above. Price 7*s*. 6*d*.

This book is a companion volume to the one reviewed above, and full details are given in it of the construction and handling of surveying instruments, and their application in the field for setting out work. It is, like the other, elaborately illustrated, and as showing the time and labour that have been spent upon it, we may mention that the principal illustrations have been reduced by photography from large size diagrams drawn to scale, thus ensuring absolute accuracy of detail. The author emphasises the desirability for the use of instruments by the best makers for the instruction of students, pointing out that an experienced man, who thoroughly understands the use and adjustment of an instrument, can better employ one which is inferior than a student whose nervousness leads him to question the result of every adjustment he attempts. This is very true, but tyros in every trade have frequently to be content with inferior tools, and although, of course, the use of instruments in the field is one of the most delicate operations which fall within the province of a surveyor, we fear that many beginners will still have to content themselves with second-hand instruments. We can confidently recommend this treatise to students as one which will enable them to properly handle and use the principal instruments employed in the field for surveying and levelling.

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Verbal Notes and Sketches for Marine Engineers.

By J. W. Sothern, Marine Engineering Academy, Glasgow. London: Whittaker & Co., Paternoster Square. Second Edition. Price 3*s*. 6*d*. nett.

The first edition of this little book was issued last year, and that it has been appreciated by those for whom it was intended is proved by the appearance of a second edition within a twelvemonth. The work consists of notes taken from the lectures on Verbals given by the author to candidates studying for the first and second class Board of Trade examinations, the matter being selected from the most important questions given up to date. There are also included in the volume a series of selected indicator cards, with defects and explanations, descriptions of water-tube boilers, patent valve gears, valve diagrams, and refrigerating machinery, etc.

The whole book has practically been re-written since its first appearance, and the result has been to render the various explanations more complete and detailed than before. Examples of "Zeuner" valve diagrams and descriptions of patent valve gears have been included in the "Engines" division of the work, and in the "Indicator" section a number of cards taken from actual practice have been added. In the former part we note a very good, though necessarily brief account of the method adopted in repairing the broken tail end shaft of the steamer "Fazilka," of the British India Steam Navigation Company, in the Indian Ocean. This difficult task, which was successfully accomplished, as will be remembered, by the chief engineer, Mr. Lachlan Brown, is, as the author points out, up to the present time unique, and as an example of mechanical skill and perseverance would be hard to beat.

In the appendix there is a useful chapter on Water-tube Boilers, their advantages and disadvantages being carefully compared and balanced. The much-debated "Belleville" boiler is described and commented on, and a good general idea of the construction of the "Babcock and Wilcox" marine boiler is given, with the assistance of excellent diagrams.

The volume contains a surprisingly

large amount of matter in a small compass, and should be found of distinct service, as a reference book, to marine engineers preparing for the Board of Trade examinations.

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Fergusson's Surveying Circle and Percentage Tables.

By John C. Fergusson, M.Inst.C.E. Published by the Author.

This is a detailed description of Fergusson's surveying circle, a device in the form of a new circle or dial, to be attached to magnetic compasses or surveying instruments, in place of the ordinary circle, which is divided only into degrees. The author claims to have solved the centesimal division of the circle by his centesimal division of the octant (45°), which can be read all round the circle from any quadrantal line, the octants being whole numbers, which again may be read in tenths, hundredths, or thousandths.

When Fergusson's surveying circle is attached to a compass or a surveying instrument, instead of the ordinary dial, the instrument is at once converted into a telemeter or range-finder, and may be read either in units or in the author's percentage divisions. This certainly facilitates the calculation of problems the solution of which would be difficult by trigonometrical formulæ, when angles are read in degrees.

Numerous examples in the use of his circle are given by the author, who specially directs the attention of engineers to his method of dealing with curves. In Fergusson's system of laying out curves, the tangent length, the long chord, the main ordinate, the external distance, and all the other lines and angles contained in the curve, are found at once arithmetically, whereas both the ordinary American and British systems involve calculations which can only be made with the use of tables.

The percentage tables, which occupy the latter half of the book, have been calculated by the author to enable any one using his circle to obtain more rapid results than would otherwise be possible.

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Bristol Tramways' Handbook—Guide to Bristol.

By Charles Challenger, Traffic Manager. Bristol: Edward Everard, Broad Street. Price *3d.*

This is an admirable little handbook and visitors' guide to Bristol. The information given in it is wonderfully full and complete, and the accompanying illustrations by F. G. Lewin are of a charming character. The design on the cover is exceptionally good. The author thinks that the best way to see Bristol is from the top of a tramway car. Be that as it may, the future visitor should make a point of purchasing one of these little guide-books upon arrival at Bristol.

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Railway Brakes.

The Westinghouse Brake Company, Limited.

This little booklet is very interesting reading, and is a useful addition to the literature of railway brakes. It makes direct and pointed comparisons between the automatic vacuum brake and the Westinghouse automatic brake, and also an improved form of the latter, the Westinghouse quick-acting brake, now in very general use. This booklet shows that during the past six years the failures to stop trains equipped with vacuum brakes, charged to faults of the brakes, were sixty in number. Similar failures charged to Westinghouse brakes were only four in number. The train mileage during this period of six years covered by the record with vacuum brakes was not quite 2¼ times that covered with Westinghouse brakes. For the past four and a half years no case of failure to

stop has been charged to the Westinghouse brake; during the same period there have been thirty-four failures reported and charged to the vacuum brake. Quickness of action throughout the train length, greater adjustability, and maximum of braking effect, are each exhibited to the highest degree in the Westinghouse quick-acting brake, and have given it a most enviable record of rescuing trains from apparent disaster.

Marine Specialities.

John Brown & Co., Limited, Atlas Works, Sheffield. Fourth edition.

This useful, and well-produced "blue book" of Messrs. John Brown & Co., Limited, has now reached its fourth edition, and in addition to containing full particulars of the firm's patent ribbed furnaces, Serve patent ribbed tubes, and Ellis and Eaves' Combination of Induced Draught, descriptions are also given of some of their other specialities for marine purposes. These last include detailed particulars of Van Ollefen's patent gear for rapid raising and lowering of water-tight bulkhead doors, as well as of special hydraulically-pressed marine shafting of the largest dimensions. The book is excellently illustrated throughout, and we may add contains a telegraphic code for some of the usual phrases in connection with the firm's business, which on account of their special nature are not included in the ordinary telegraphic codes.

ENGINEERING NOTES.

Ventilating and Heating.

We are asked by the Blackman Ventilating Co., Limited, to state that they have acquired from Mr. James Keith, C.E., his well-known business as heating engineer (with departments in gas and hydraulic work), carried on at 27, Farringdon Avenue, E.C., and at his foundries and engineering works in Arbroath. This union of two of the largest businesses, in ventilating and heating respectively, in this country, rests argely on the essential dependence of these two branches upon each other for satisfactory development and production. Under the new name of James Keith and Blackman Company, Limited, the Company has within itself the means of rapid first-hand production of all the best modern appliances for warming and ventilating, also the practical training, technical knowledge, and wide experience of the principals and staffs thus combined.

Another Moving Platform for Paris.

Visitors to the Paris Exposition will doubtless remember the moving platform which was operated by Westinghouse motors. This method of electric propulsion proved such an attractive feature of the Exposition that the Paris authorities are now considering the installation of another electric platform. The novel feature of this installation is that it is to be built underground. The proposed track is to run under the Avenue de l'Opéra, the Boulevards, Boulevard Sebastopol, Rue Turbigo and Rue de Rivoli—a distance of 10 kilometres. The line is to consist of four platforms: the first will be stationary, the second will move at a speed of about three miles an hour, the third and fourth at the rate of about six and eight miles an hour respectively.

Interesting Electrical Development.

Messrs. Ernest Scott and Mountain, Limited, Close Works, Newcastle-on-Tyne, have, we are informed, secured an important contract in South Wales for the Port Talbot Iron and Steel Co., in connection with the new steel rolling

mills which that firm are erecting. As this mill will be one of the most modern in this country, and one of the first new mills in which a complete equipment of electrically driven machinery has been adopted, a few particulars of the plant may be of interest. The installation consists of a compound horizontal engine capable of developing 600 h.-p. with a steam pressure of 150 lb. per square inch, driving on to a pair of Messrs. Scott and Mountain's generators, each generator being capable of giving an output of 200 kilowatts, or collectively 400 kilowatts, equal to 540 electrical h.-p. at the terminals. The current is utilised for working a 60-ton crane for the casting pit, this crane being fitted with four electric motors, viz., one motor for heavy lifts, one motor for low lifts and for tilting the ladle, one motor for longitudinal traverse, and one motor for cross traverse. Over the casting pit a 10-ton crane of the three motor electric type is being fitted, dealing with the ingots, and bringing them to the rolling mills. A 25-ton crane is placed in the rolling mill, and is utilised for changing the rolls, and also for taking the rolls to the roll turning and mechanics' shop, which is placed at the end of the mill, so that the rolls can be lifted out of the housings and dropped straight into the roll-turning lathes. The works are also to be lighted throughout by arc and incandescent lamps, driven by a "Scott and Mountain" independent generator.

Useful Machinery.

We have received from Mr. Charles D. Phillips, Emlyn Works, Newport, Mon., a copy of his new catalogue of machinery and specialities for builders and contractors. Particulars and illustrations are given in it of engines, boilers, pulleys, shafting, belting, etc., as well as of the latest types of saw mill and other machinery.

The "Diesel" Engine: Correction.

We regret that, in our April issue, in describing the "Diesel" engine, we wrote of it as "the first British-made 'Diesel' engine," this statement being inaccurate. The Mirrlees Watson Co., Limited, of Scotland Street, Glasgow, made the first "Diesel" engine in this country two or three years ago, and repeated tests have been made on it, not only by themselves, but by others. The engine is still at their works at Glasgow.

NEW PATENTS.

(Selections from recently published Patent specifications. Complete copies may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, W.C. Price 8d. each.)

No. 1,923. "Steam-engine air-pumps." T. Thompson, of Arlicote, Westcombe Hill, Blackheath, Kent. Dated January 30th, 1900.

The air pump cylinder is arranged vertically, the upper surface of the piston forming the working face. The lower end of the cylinder is provided with ports, situated above the piston when in its lowest position, and connected to the condenser at some point well above the water. The part of the air-pump piston-rod next to the piston is hollow, and provided with a valve, the lift of which can be regulated. The hollow part of the piston-rod is provided with ports working in conjunction with ports in a stuffing-box connected to a supply of water under head or pressure, so that when the piston is at the bottom of its stroke, water is forced into the cylinder above the piston, and so seals it. The upper end of the cylinder is surmounted by a perforated plate, whose perforations are closed by balls kept in position by a cover plate or grid. A small water-chamber is arranged immediately over the cylinder, and provided with an overflow.

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No. 4,015. "Thrust bearings or footsteps for revolving shafts." T. C. Fawcett, Ltd., and J. D. Fawcett, all of Whitehouse Engineering Works, Hunslet Road, Leeds. Dated March 2nd, 1900.

A hydraulic bearing to receive the end thrust of revolving shafts is formed by pumping into a reservoir—provided between the bearing and the end of the shafting, or a collar boss or flange thereon—oil or other lubricant, or water under suitable pressure, to establish and maintain a hydraulic lubricant buffer or cushion. Means are provided in combination with the reservoir or chamber to prevent escape of the lubricant or liquid.

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No. 8 of 1900. J. Klein, of Manchester, for "Condensers for Steam-engines."

A condensing system for steam-engines, having a jet condenser arranged at about the working barometrical level, or as near thereto as practicable, an air-pump connected with that part of the condenser near which the water enters, and a separate water pump, having its suction-pipe connected with that part of the condenser near which the steam enters.

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No. 4,063. "Gripping devices of overhead travelling and other hoists and cranes." T. B. Mackenzie, of 342, Duke Street, Glasgow. Dated March 3rd, 1900.

Dogs or cross-levered grippers are jointed to a lower block, their upper arms crossing above the block, and connected to an upper block or blocks fitted with pulleys, round which pass ropes or chains from a winding-barrel. A third rope or chain is also wound on the barrel and passes down to and round a pulley on a third block, and thence up to a second winding-barrel. The third block is connected to the lowermost block.

No. 4,076. "Crushing and grinding machines." R. F. Pochin and H. S. Pochin, both of St. Margaret's Ironworks, Watling Street, Leicester. Dated March 3rd, 1900.

The toggle plate of the crushing or grinding machine is held by a rod or link having a buffer, spring or balance weight fastened to a fixed point, by which the toggle plate is prevented from getting out of position.

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No. 4,100. "Dredgers." T. Modus, of Charlottenburg, Germany. Dated March 3rd, 1900.

Two boats or pontoons, which may also serve as hoppers, are connected together, and are adapted to carry frames, in which the shaft of the lifting wheel has its bearings. These bearings are so arranged that they may be raised and lowered by means of a hand-wheel.

The lifting wheel is made of wood or metal, and is of large diameter, varying in size according to the special circumstances under which it is required. It is closed on its sides, which are provided with water-tight doors. The periphery of the wheel is provided with more or less tangentially inclined blades, forming chambers with the sides. The chambers bring the soil to the top, and allow it to flow away at the highest point of the wheel, so that the wheel may be completely immersed under water, and its whole height utilised. Port-holes are provided on the periphery of the wheel, rendered water-tight by transparent coverings of glass.

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No. 4,234. "Core-boxes for founders' use." A. Scott, of 5, Canonbury Place, Canonbury, London. Dated March 6th, 1900.

A frame is formed, in which any number of weights are free to slide up and down a short distance, their lower ends being of the same shape as the upper ends of the projecting cores. The weights are so arranged that each comes over an orifice in the core-box cover; consequently, when it is lifted, each of the weights presses upon the top of the corresponding core, and by tending to press it downwards, prevents it from breaking away from the body core and rising with the cover. Springs may, in some cases, be substituted for the weights.

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No. 5,664. "Manufacture of metal columns." R. Rau, of Schiltisheim-Strassburg, Germany. Dated March 26th, 1900.

In the casting of the column, a wrought-iron tube is substituted for the usual core, and this tube remains in the column and imparts the necessary rigidity thereto, while a cast-iron jacket may be produced in any desired architectural form, and a special ornamentation thus rendered unnecessary.

In one method of carrying out this invention the mould is set either vertically or slantingly, and the lower end of the core-tube is connected with a water supply, for the purpose of keeping down the temperature of the wrought-iron tube.

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No. 6,245. "Steam generators." A. J. Boult, a communication from O. Buogo, of Palermo, Italy. Dated April 3rd, 1900.

The boiler tubes of the steam generator contain hermetically closed and concentrically arranged inner tubes, for the purpose of reducing the volume of water contained in the said boiler tubes, the said inner tubes having a smaller diameter when nearer to the fire-grate and hot blast, and a larger diameter when at a greater distance from the fire-grate and hot blast.

End of Volume V.